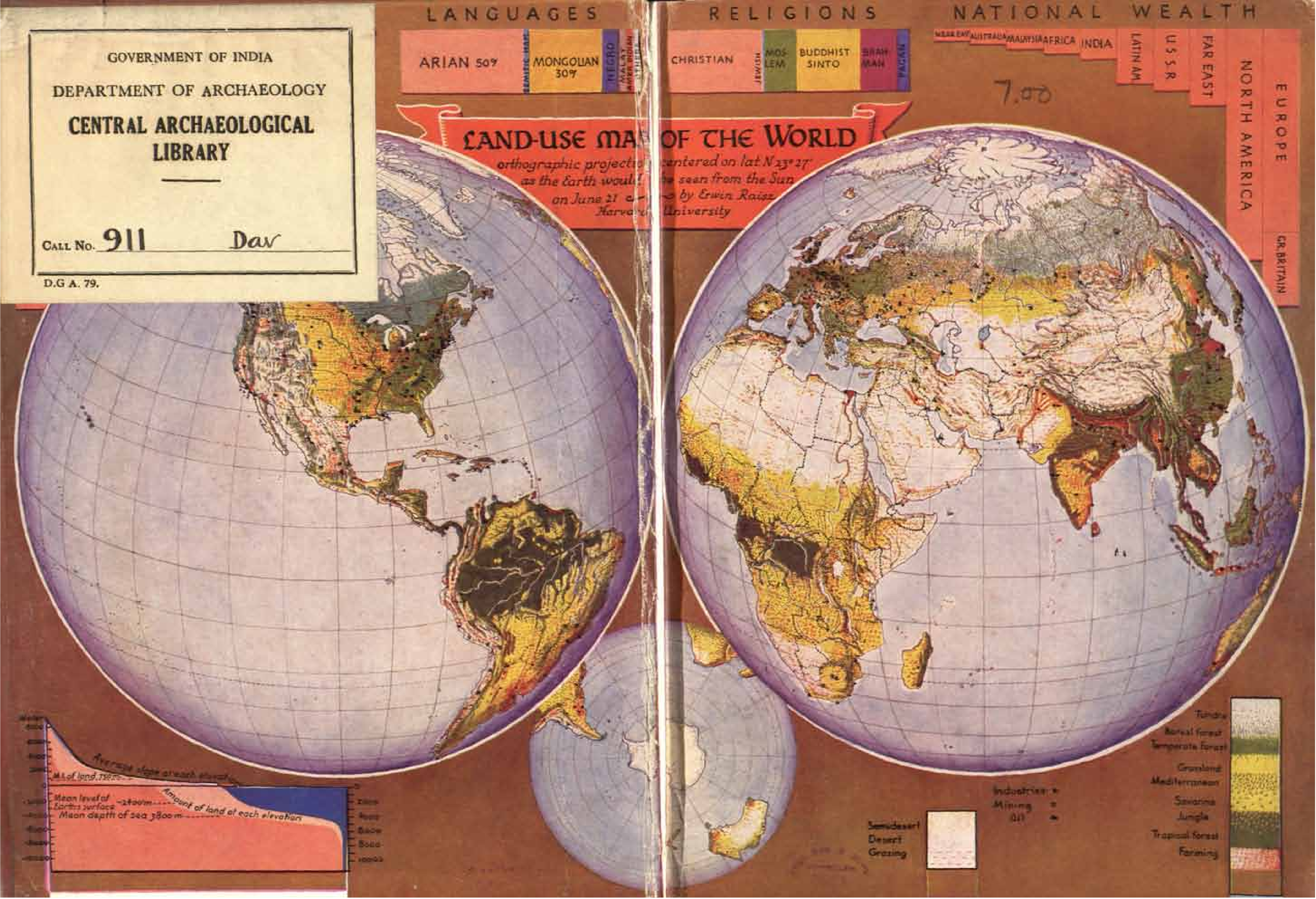
LANGUAGES
ARIAN 50%
MONGOLIAN 30%
NEGRO
RELIGIONS
CHRISTIAN
JEWISH
MOSLEM
BUDDHIST SINTO
BRAHMAN
PAGAN
NATIONAL WEALTH
AUSTRALIA
MALAYSIA
AFRICA
INDIA
LATIN AM.
U.S.S.R.
FAR EAST
NORTH AMERICA
EUROPE
GR. BRITAIN
7.00
LAND-USE MAP OF THE WORLD
orthographic projection centered on lat. N 23° 27'
as the Earth would be seen from the Sun
on June 21
by Erwin Raisz
Harvard University
Average slope at each elevation
Amount of land at each elevation
Mean level of Earth's surface -2400m
Mean depth of sea 3800 m
Semidesert
Desert
Grazing
Industries
Mining
Oil
Tundra
Boreal forest
Temperate forest
Grassland
Mediterranean
Savanna
Jungle
Tropical forest
Farming

The EARTH *and* MAN

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The EARTH *and* MAN

A HUMAN GEOGRAPHY

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REVISED EDITION

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PREFACE

The Earth and Man is a textbook, planned in this edition, as in the first, to meet the needs of beginning geography classes in American colleges and universities. Like the first edition, also, it is a treatment of man and his economic activities in their areal, environmental settings: a study of terrestrial unities. This is the unique field of the subdivision of human knowledge known as "geography." Indeed a geography from which human interests are excluded "has never existed except in the minds of specialists." Manifestly, background material from the fields of other subjects is necessary for such a study. Therefore it has been introduced, but in its proper place and importance in the geographical treatment.

Though both are alike in most respects, this edition differs from the first in some important particulars. Changes which will be noted are of two classes: first, those of organization; second, those involving subject matter and illustrations.

Those of the first class include: (1) increase in the number of chapters and greater uniformity in their length and difficulty, as an aid to assignments; and (2) some rearrangement of subject matter to permit more effective use of the book in either a short or a more extended course.

Those of the second class include: (1) extensive revision of certain chapters and use of current data, elimination of some comparatively unimportant text, and addition of new chapters; (2) substitution of more timely illustrations, use of more relatively large-scale world maps, and addition of many new diagrams and maps; (3) additional emphasis on the part geographical conditions play in the life of the individual, national welfare, and international relations.

Considering the use for which this book is designed, two objectives have been kept in mind in its preparation: first, to supply a background of factual material and principles of value to all students; second, to establish certain facts and principles concerning regional possibilities as affected by environmental conditions, both singly and in selected combinations, upon which those planning additional work in the subject may build. Complete synthesis of these factors has been left for future regional courses.

This book is not planned as a compendium of geographical knowledge, but as a treatment of certain material from the entire field of the subject to secure designated results. In major part, inquiry is confined to, and emphasis

is upon, how and why man's visible impress on the earth's surface, as manifested by his works, is affected by natural and regional inheritance. Even the subject matter considered within the range indicated is not all-inclusive, but selected to supply illustration and an adequate basis for discussion by the two classes of students for whose use the book was planned.

In evaluation of the function of environment, as reflected by human activities and their tangible results, man is considered the active agent, environment the passive; either presenting or denying opportunity, but never forcing acceptance. With this as a premise, it is conceived that man cannot "conquer nature," but that he exists only by her sufferance, succeeding only insofar as he regulates his activities to profit from such opportunity as presented.

The attempt has been made to consider subject matter within the range of student interest and ability, and to present this material in such form that it can be understood by students. This necessitates simplified treatment, with a minimum of technical terminology, if the objectives stated are to be achieved. With this in mind, also, certain topics are introduced in early chapters and their treatment amplified later, in a more appropriate place in the discussion, for experience indicates certain advantages to such a procedure, despite the objection of some repetition. Since this text is designed as a place from which to depart, not as a geographical encyclopedia, the instructor has been left free to use either supplementary local illustrations or those from his own experience, which he can make more real. A special attempt has been made to avoid use of maps and illustrations not pertinent to the discussion, and to encourage use of those included by their proper location with reference to the text, and by many extended captions.

The facts considered are the observable features of areas, individually and in their relationships, which fall into the following groups: (1) climatic, surface, drainage, and other similar elements, unmodified by man, which, in their sum total, constitute the *natural environment;* (2) buildings, transportation lines, mines, and other works of man, which are elements of the *cultural environment;* (3) existing vegetation cover, drainage, and other material areal aspects which represent a present end product of original conditions as modified by man, always present where he has made his home; and (4) man and his economic activities. Therefore the *facts* considered are those finding material expression, though the accompanying discussion and explanation are not necessarily thus limited.

For purposes of presentation, the treatment is divided into six parts, as follows:

Part I. Introduction. This sketches briefly the growth of geographic knowledge and the development of the field of geography.

Part II. Man: His Distribution and Numbers. This subdivision of the text is devoted to a discussion of: (1) the distribution and numbers of man; (2) the

environmental and other factors which affect his distribution and numbers; and (3) the significance of these two and other aspects of population in both internal and international affairs.

Part III. Man and Environment. This section deals with certain facts and principles with which geography is concerned: (1) the interaction between man and environment at different stages of human development; and (2) changes in environment resulting from the operation of both natural and human agencies. Where practical considerations indicate its desirability, man's use and misuse of natural opportunity are discussed concurrently.

Part IV. The Elements of the Physical or Natural Environment. In this division, individual factors of the unmodified natural environment such as climate, soils, land forms, natural drainage, mineral wealth, and contact with the sea are considered separately, both to secure a necessary factual knowledge of each, and an understanding of the limitations each imposes on the potentialities of an area for effective human use. In view of the dual objective, it is apparent that not all the material included in this section lies within the field of geography proper.

Part V. How Man Obtains His Livelihood. This part deals primarily with man's economic activities and their environmental basis, the attempt being made to take into account the combined effects of several environmental factors to explain definite uses of specific areas. This is designed to illustrate possible profitable use of the isolated facts considered earlier, and to serve as an introduction to the study of regions in later courses. Since planned to a considerable extent to be illustrative only, admittedly this may be only a partial synthesis in some cases.

Part VI. The Appendix. This last section permits consideration of additional subject matter. It includes an account of the development of mapping; a discussion of latitude, longitude, and map projection, with many illustrations; a consideration of map scales, direction on maps, and representation of elevation and relief; a description of methods of land survey; an account of solar relations; a statement of how time is measured; a modified Köppen climatic classification, with alternative names for the climatic types; an American system of soil classifications; and a chapter of tables. Though this material does not find a proper place in the body of the text, some chapters may be of value to supplement earlier, less extended treatment of certain topics. Moreover, all are as possible of use as they would be if inserted in earlier sections where they do not belong, yet none need be assigned unless desired.

The text proper, then, includes a consideration of: (1) man's numbers and distribution; (2) the interaction of environment and man; (3) how man makes his living in various environmental settings at different stages of his development; and (4) the distribution of man's economic activities. Throughout, changed and changing environmental conditions and values resulting

from human activities and progress are stressed, not only as they affect the life of the individual, but as well the existence of the community and international relations. It is believed that this treatment ensures both continuity in presentation and functional values which are highly desirable. This organization of subject matter is based on experience, not on theoretical considerations only, for it has been tested and found effective in the classroom, which is the laboratory where all texts must be proved.

A list of questions and exercises accompanies each chapter. These do not cover the subject matter completely, nor are they limited entirely to the subject matter presented. They will, however, serve the student by enabling him to test his mastery of the material, and they will also afford a basis for class discussion, if it is desired to make such use of them. Selected references at the ends of the chapters are not bibliographies of source materials, but only what the heading indicates: some suggested supplemental reading which may be done to advantage by intellectually curious students, or which may be assigned for class reading if it is desired to amplify on the text treatment of individual topics. To make these lists of maximum practical value, they contain no references to periodical literature, but are limited to books commonly in libraries. Further, a brief statement of the topics treated in each is appended as an aid to the student. If more extended bibliographies are desired, they are available in the selected references.

Preparation of *The Earth and Man* would have been impossible without source material. Therefore the author feels a deep sense of obligation to those who, by supplying facts and ideas directly, and by the indirect suggestion of ideas, have contributed to its past success and to such approval as this revision may meet. In some cases, the source of the facts or ideas may be unknown, yet it is apparent that few of either are original contributions, for this, like all texts, is mainly a compilation of *selected* material, and such merit as it may possess is determined by the organization and presentation of the subject matter.

Government publications, particularly those of the National Resources Board and the Bureau of Reclamation; various Commissions; and the Department of Agriculture, including the Weather Bureau and the Soil Conservation Service, have been drawn on freely for facts. Many state agencies and private concerns have likewise supplied similar material.

Prominent in the list of individuals who have made *The Earth and Man* a possibility are Professor Mark Jefferson and Dr. Carl O. Sauer, for they, by their earlier teaching, are the source both of facts and many of the ideas. Probably as well, both consciously and unconsciously, members of the departmental staff, both present and past, have left their impress on the author's thinking, as a result of informal discussions and the organization of work in the department.

Special obligation is accorded to Dr. Ralph H. Brown for a critical reading of practically the entire manuscript in its final version. The author

also wishes to express his deep sense of obligation to Dr. Robert B. Hall, Dr. J. Russell Whitaker, and several others unknown to him, for critical readings of the entire manuscript of the first edition.

Specific acknowledgment of indebtedness is, moreover, due Dr. Kirk Bryan for valuable descriptions of the arid regions of southwestern United States; Dr. W. Elmer Ekblaw for his generous permission to use the material on the Polar Eskimo; Professor J. W. Hoover, who supplied most of the facts of Navajo and Hopi economies; Dr. M. C. Kahn for data on the Djuka; Dr. S. S. Visher for certain population data and assistance with the section devoted to treatment of the weather elements; and Dr. Derwent Whittlesey for his discussion of nomadic herding.

In this revision, the author has profited from the critical reading of several chapters by colleagues who are specialists in the fields on which these chapters of the text have drawn for facts. Those who have been of assistance in this manner include: Dr. Frederick J. Alway, who read the chapters on soils and soil classification; Dr. William S. Cooper, who did the same for the sections dealing with plant life; and Dr. George M. Schwartz, who read and criticized the chapters related to some aspects of geology, particularly those dealing with minerals and mining. Dr. Wilson D. Wallis has also been very helpful on anthropological questions. Among those mentioned above as having read certain chapters critically, Dr. William S. Cooper and Dr. George M. Schwartz have used the text in classes and have suggested improvements in sections other than those in their fields of specialization. Valuable suggestions on specific points have likewise been made by a long list of others, among whom should be mentioned Dr. Griffith Taylor and Professor Edward G. Pleva. Based as they have been on intimate knowledge of certain areas, or classroom use of the text, they have been very helpful.

Acknowledgment of indebtedness is also accorded the individuals, firms, societies, state and other governmental agencies, both in this country and elsewhere, contributing many of the photographs and other illustrations used. To them, it has been possible to extend credit in connection with individual illustrations in both the first edition and this revision.

Though advantage has been taken of many helpful suggestions, it is realized that imperfections of several types must still exist. Therefore additional constructive criticism is welcomed to the end that such defects may be remedied when the opportunity presents itself, so that the needs of students may be met more adequately.

Darrell Haug Davis
UNIVERSITY OF MINNESOTA

CONTENTS

PART I. INTRODUCTION

1. The Growth of Geographic Knowledge and the Field of Geography . 1

PART II. MAN: HIS DISTRIBUTION AND NUMBERS

2. Man: His Numbers and Distribution 9
3. Factors Affecting the Population Pattern 18
4. Economic Activities and the Population Pattern 29
5. Population Changes and Population Problems 42

PART III. MAN AND ENVIRONMENT

6. The Environment: Its Factors and Functions 52
7. The Changing Environment: Natural Agencies Producing Change . 66
8. The Changing Environment: Human Agencies Producing Change: Deforestation, Fires, and Drainage 78
9. The Changing Environment: Human Agencies Producing Change: Grazing, the Extractive Industries, and Irrigation . . . 90
10. The Changing Environment: Human Agencies Producing Change: Agriculture 101

PART IV. ELEMENTS OF THE PHYSICAL OR NATURAL ENVIRONMENT

11. Climatic Elements: Sunshine and Temperature 114
12. Climatic Elements: Atmospheric Moisture and Dust . . . 126
13. Climatic Elements: Fogs, Clouds, and Precipitation . . . 135
14. Climatic Elements: Winds 148
15. Climatic Elements: Winds and Weather 160
16. Soils 170
17. Inland Waterways and Navigation 184
18. Inland Waters and Power Development 202
19. Inland Waters and Irrigation 214
20. Water Supply 226
21. Miscellaneous Uses of Inland Waters 238
22. Surface Features: Lowlands 251
23. Surface Features: Highlands 272
24. Minerals 291
25. The Oceans and Their Coasts 308
26. Life Forms: Plant and Animal 325
27. Space Relationships 349

PART V. HOW MAN OBTAINS HIS LIVELIHOOD

28. Primitive Hunting and Fishing Populations 364
29. The Grasslands and Grazing: Nomadic and Commercial . . . 380
30. Primitive Agriculture 397
31. Oriental Agriculture 413
32. Occidental Agriculture of Intermediate Latitudes . . . 429
33. Plantation Agriculture 447
34. Forests and the Forest Industries 463
35. Mining 479
36. Fishing and Sea Hunting 497
37. Transportation 514
38. Commerce and Industry 539
39. Cities and Urbanization 558
40. Afterword 585

PART VI. APPENDIX

41. The Development of Mapping 591
42. Map Projection 599
43. The Earth's Dimensions and Mathematical Location . . . 612
44. Map Scales 616
45. Direction on Maps and Magnetic Declination 618
46. Representation of Elevation and Relief on Maps 621
47. Land Survey 624
48. Solar Relations 627
49. Measurement of Time 632
50. Climatic Types 637
51. Weather Prediction 651
52. Soil Classification 657
53. Supplementary Climatic Maps 667
54. Miscellaneous Tables 674

INDEX 685

LIST OF PICTURES

Figure

9. Kentucky Mountain home on Messer Branch 20
10. Valley of Greasy Creek, eastern Kentucky 23
11. Wheat harvest in the Saskatchewan 24
12. A modern ocean liner 25
15. A group of migrating Kalahari Bushmen 31
16. Nomadic Kirghiz and their "yurt" 32
17. A Canadian ranch, in Alberta 33
18. A Congo basin agricultural village 34
19. An agricultural scene in southern Japan 35
21. An agricultural scene in northern Illinois 37
22. A Labrador fishing village 38
27. Two types of Nebraska sod house 54
28. Fishing in the Shinano River, Echigo Plain, Japan 55
29. El Ued, an oasis in the Sahara 55
30. The "stone money" of Yap 56
31. Stock farm in the Bluegrass of Kentucky 58
32. Typical farm home in the Bluegrass of Kentucky 58
33. Typical Kentucky Mountain topography 60
34. Typical Australian black 61
35. Australian blacks building a "gunyah" or shelter 62
36. Hibernia Bank Building, after the San Francisco earthquake . . 67
37. Destruction of Hoopulua, Hawaii, by a lava flow 68
38. Flood stage of the Pea River, Alabama 70
39. Effects of drought, Cimarron County, Texas 71
40. Tornado cloud and funnel, Hardtner, Kansas 72
41. Tornado damage, Murphyboro, Illinois 73
42. A Worcester, Massachusetts, street after the New England hurricane . 74
43. Seaside Avenue, Atlantic City, New Jersey after the hurricane of September, 1944 75
44. After the Blackwater fire, Wyoming 76
46. A virgin stand of white pine in northeastern Minnesota . . . 80
47. A virgin stand of hardwoods in North Carolina 80
48. Cutover land in Menominee County, Michigan 81
49. One of the better farms of a cutover area in northeastern Minnesota . 81
50. Spud Hill fire in the Columbia National Forest, Washington . . 82

52. The great dike at Wieringen, Holland 85
53. Typical "polderland" in agricultural use, Zuider Zee drainage project, Holland 86
55. Cattle grazing on good short-grass range, Montana 91
56. Cattle and artificial stock-watering pond, Wyoming 91
57. A man-made desert resulting from misuse of natural opportunity . 92
59. A coal mine in the Karaganda field, Siberia 94
61. Farmstead in the irrigated Kittitas Valley, Washington . . . 97
62. *Top:* An average farmstead in the Belle Fourche Irrigation Project, South Dakota. *Middle:* An "alkali spot" in the Belle Fourche Irrigation Project. *Bottom:* Abandoned farm and buildings, Belle Fourche Irrigation Project 98
63. Sheet erosion, Latah County, Idaho 102
64. Initiation of gullying, Fillmore County, Minnesota 103
65. Gully development by "headwater erosion," Lavaca County, Texas . 103
66. Development of gullies, Floyd County, Georgia 104
67. Severe gullying, Lafayette County, Mississippi 104
69. Fluctuation of stream flow, Obion Creek, western Kentucky . . 106
70. Corn and tobacco on a steep slope, Anderson County, central Kentucky 106
71. Removal of all soil and exposure of bare rock by soil erosion, Anderson County, central Kentucky 107
72. An approaching dust storm, Prowers County, southeastern Colorado . 108
73. Result of wind erosion, Beadle County, South Dakota . . . 108
74. Strip cropping, Winona County, Minnesota 109
75. Contour plowing and strip cropping, Lancaster County, Pennsylvania . 110
76. Fresh terraces, Houston County, Minnesota 111
77. Basin furrowing, near Humboldt, Nebraska 112
81. Citrus orchard on an alluvial fan, California 119
88. Dust storm, southeastern Colorado 132
91. Cumulus clouds 138
92. Stratus clouds 138
93. Cirrus clouds 139
94. Sleet damage, Litchfield, Connecticut 140
95. Hail damage to tobacco 141
96. Snow, an aid to travel in northern Siberia 142
109. Tornado damage 158
116. Results of a heavy rain on a cultivated slope, northwestern Missouri . 171
119. Active dunes in the Arkansas River Valley, northwestern Kansas . 177
120. Roadside cut in loess, western Kentucky 177
124. Dock and packet boats, Paducah, Kentucky 185
125. Dam and Lock 7, on the Upper Mississippi River, near La Crosse, Wisconsin 186
127. Loading lumber at Portland, Oregon 188
128. Bonneville Dam, on the Columbia River 188
129. Port facilities at Stockton, California 189
130. Freight terminal and terminal facilities at Louisville, Kentucky . . 190
131. Coal mine and barge, on the Kentucky River 190
132. Looking down on the business section and harbor of Duluth, Minnesota . 192
133. Loading iron ore at Duluth, Minnesota 192

134. Locks at Sault Ste. Marie 193
135. Typical lake freighters discharging iron ore at Cleveland, Ohio . . 194
137. Motorized steel oil barge, on the New York State Barge Canal . . 196
139. Loading cotton and other freight, Houston, Texas . . . 197
140. The canal network north of Amsterdam, Holland . . . 198
141. *Top:* A scene on the delta of the Shinano River, Japan. *Bottom:* The busy Sumida River, Japan 199
144. Downstream face of Wheeler Dam, Tennessee River . . . 206
146. Boulder Dam and Lake Mead 209
149. Coulee Dam and the surrounding country 212
150. Irrigated strawberry farm, southern Michigan 215
151. Irrigation ditch and rice paddies, Japan 215
152. A Los Angeles County orange grove 216
153. Irrigation by well, northeastern Colorado 217
157. *Top:* The Imperial Dam and the All-American Canal. *Bottom:* The All-American Canal crossing the desert 222
160. A cistern in western Kentucky 229
161. A sinkhole in central Kentucky 230
163. *Top:* The source of water supply for Boulder, Colorado. *Bottom:* The Beacon Hill reservoir of the Seattle water system 232
164. *Top:* Parker Dam and reservoir, on the Colorado River. *Bottom:* Intake pumping plant, two miles below Parker Dam 234
166. One of the Amethyst Lakes, Jasper National Park, Canada . . 239
167. Bathing in the Iowa River, near Iowa City, Iowa 239
168. Vernal Falls, Yosemite Valley, California 240
169. Lake Tahoe, California 241
170. Cabin camp on the Baptism River, Minnesota 242
171. Summer cottage in southern Michigan 242
172. The High Falls of the Pigeon River, Minnesota 243
173. The bathing beach at Boonesboro, Kentucky 244
174. Levee on the Mississippi River 245
175. A contrast in stream flow, Minnehaha Falls, Minnesota . . . 247
178. Hilly topography of the inner margin of the Gulf Coastal Plain, western Kentucky 253
179. Harvesting spinach, near Norfolk, Virginia 254
180. *Top:* Log house in a hilly portion of the Gulf Coastal Plain. *Bottom:* "Dog trot" house, western Kentucky 255
182. *Top:* Living conditions, alluvial plain of the Mississippi River. *Middle:* Clearing and house set on posts, alluvial plain of the Mississippi River. *Bottom:* Schoolhouse set on posts, alluvial plain of the Mississippi River 258
183. Alluvial plain of the Mississippi River under levee 259
185. Outwash plain and terminal moraine, southern Michigan . . . 262
186. Pigeon Prairie, southern Michigan 262
187. Prosperous dairy farm in southern Wisconsin 263
188. Exceptionally stony moraine, Sweden 263
190. Harvesting grain on the former bottom of glacial Lake Agassiz . 265
192. *Top:* House at Great Crossing, Inner Bluegrass region, Kentucky. *Bottom:* Scene on the Paris Pike, near Lexington Kentucky. . . . 267

193. *Top:* Typical farmstead, Eden shale belt, Bluegrass region, Kentucky. *Bottom:* Winding ridge road, Eden shale belt, Bluegrass region, Kentucky 268
194. *Top:* One of the better farm houses, Outer Bluegrass region, Kentucky. *Bottom:* Topography and crops of the Outer Bluegrass region, Kentucky 269
198. Road up the valley of Quicksand Creek, Kentucky Mountains . 278
199. The road goes over a "mountain," eastern Kentucky . . . 278
200. A steep slope in corn at the head of a "cove," Kentucky Mountains . 279
201. A Kentucky Mountain home 280
203. Typical farmstead and topography of the glaciated upland of northeastern Minnesota 282
204. Trucking out white pine logs, northeastern Minnesota . . 283
205. An abandoned farm in northeastern Minnesota 283
207. A heavy grade on the Canadian Pacific Railroad, in British Columbia 285
208. Lake Louise, in the Canadian Selkirks 286
209. A scene in the Canadian Selkirks 286
210. Crater Lake, Oregon 287
211. *Left:* Yosemite Falls, California. *Right:* Lower Falls and the Grand Canyon of the Yellowstone, Wyoming 288
226. Looking easterly across Elliott Bay and the city of Seattle . . 319
227. Beach scene, Miami, Florida 320
228. Pemaquid Point Lighthouse, on the coast of Maine . . . 323
231. *Top:* Tropical rain forest, southern Nigeria. *Bottom:* A waterway choked with vegetation in the drainage of the Rio Negro, Brazil . 329
232. A virgin stand of beech, North Carolina 330
233. Palm and thorn forest, Tanganyika, Africa 331
234. California "chaparral" 332
235. *Top:* Scattered oaks and grassland of the Coast Range of California. *Bottom:* Coniferous forest of the Sierras, California . . . 333
236. A redwood forest in northern California 334
237. A Puget Sound Douglas fir forest 335
238. Virgin longleaf pine forest, Florida 336
239. A mature stand of white pine, northern Minnesota . . . 337
240. Taiga, or the subarctic forest of Siberia 338
241. A stand of cypress, South Carolina 338
242. Savanna grassland, Africa 339
243. Bluestem prairie, Nebraska 340
244. Steppe grassland, Colorado 341
245. *Upper left:* A giant Joshua tree, California. *Upper right:* Giant columnar cactus, Arizona. *Bottom:* Sagebrush, Utah 342
246. Tundra of the Lower Ob River, Siberia 343
247. Reindeer and tundra of northwestern Siberia 344
250. The lower end of Manhattan Island 353
259. Ak-a-ting-evah's "tupic," his summer home 366
260. Sip-soo's "igloo," in a winter village 367
261. Two Eskimos building a snow house 368
262. Eskimo kayak 368
264. A group of Kalahari Bushmen and their reed shelter . . . 371
265. An old Bushman and child 372

266. Kalahari Bushmen, women and children 374
268. A family of Pygmies in the Ituri Forest 376
269. A typical Pygmy of the Ituri Forest 377
271. Kirghiz migrating to summer pastures 383
272. Kirghiz women milking a yak 384
274. Typical Navajo range, with band of sheep and goats . . . 386
275. *Top:* Summer hogan built of short juniper limbs. *Bottom:* Winter hogan 387
276. *Top:* Navajo cattle and poor range. *Bottom:* Navajo women weaving a rug 388
278. Ranch and sheep, near Calgary, Canada 393
279. A California cattle ranch in the Salinas Valley 394
282. A Saramaccaner village, Dutch Guiana 403
283. A Djuka "corial" or dugout negotiating a rapids . . . 404
284. *Left:* A Saramaccaner man in typical attire. *Right:* A Saramaccaner women pounding cassava flour 405
285. Djuka drummers and elaborately carved drums . . . 406
287. The pueblo of Walpi 408
288. A portion of the pueblo of Mishongnovi 409
289. A Hopi melon patch, near Hotevilla 410
291. An agricultural scene in east central China 415
292. A remarkable case of terracing in the Philippines . . . 416
293. Rice land in east central Honshu, Japan 417
294. An agricultural scene in late April, on the rice lands of the Ishikari Plain, Hokkaido 419
295. Plowing a wet rice paddy in southern Honshu . . . 420
296. An agricultural scene on the Kwanto Plain, Japan . . . 421
297. An agricultural scene in late May, eastern Honshu . . . 422
298. A Japanese threshing machine in full swing 424
299. Buckets of fertilizer on their way to the farm, Kyoto, Japan . . 425
300. Fertilizing sweet potatoes, Japan 426
301. Farm homestead and silo, Ishikari Plain, Hokkaido . . . 427
303. Hereford yearlings in Sudan grass pasture, eastern Nebraska . . 432
304. Harvesting tobacco, central Kentucky 434
305. Harvesting wheat in the Palouse Hills, eastern Washington . . 436
306. Wheat threshing in southern Alberta, Canada 437
307. The Kuban State Farm, U.S.S.R. 438
308. Harvesting wheat with a combine, Sower Collective Farm, U.S.S.R. . 438
309. A south-central Wisconsin dairy farm 440
310. A prosperous dairy farm in the Willamette Valley, Oregon . . 441
311. Irrigating a field of lettuce, New Jersey 442
312. Threshing peanuts, near Norfolk, Virginia 443
313. Irrigated apple orchard in eastern Washington 444
315. Bananas ready for harvest, Cuba 450
316. Plowing to prepare for planting, planting, and harvesting of sugar cane, Cuba 453
317. Hauling sugar cane from the field to the loading platform, Cuba . 452
318. A trainload of sugar cane, Cuba 453

319. *Top:* A new planting of rubber trees, northern Sumatra. *Bottom:* An eight-year-old planting of rubber trees, northern Sumatra . . 455
320. Tapping a rubber tree on an East Indian plantation . . . 456
321. *Top:* The home of the manager of a rubber plantation, northern Sumatra. *Bottom:* Houses of the Indonesian laborers on a rubber plantation, northern Sumatra 457
323. *Top:* Nursery at Belterra, with budded trees. *Bottom:* Hillside planting of rubber trees, Fordlandia 460
324. *Top:* Piling spruce pulpwood, Minnesota. *Middle:* Hauling tie cuts with a caterpillar tractor, Wisconsin. *Bottom:* Driving the Littlefork River, Minnesota 468
325. *Upper left:* Cutting shortleaf pine, Arkansas. *Upper right:* Loading a truck with logs, Texas. *Bottom:* Loaded log train, Arkansas . . 469
326. *Upper left:* Preparing a tree for the collection of turpentine, Florida. *Upper right:* Pouring gum from cup into hand barrel, Florida. *Middle:* Gathering the take of the "dip squad," Florida. *Bottom:* Turpentine distillery, Florida 470
327. Caterpillar tractor operating in a Puget Sound forest, Washington . 471
328. Loading large timbers on a ship, Portland, Oregon . . . 472
329. Mechanized logging in the Siberian taiga 474
330. *Top:* Cutover land in the first stages of clearing, Upper Peninsula of Michigan. *Bottom:* The results of 30 years of clearing on the same farm in the Upper Peninsula of Michigan 476
331. Hydraulic gold mine, California 480
332. "Strip-mining" of coal, Indiana 482
333. *Top:* Oil derricks, Signal Hill, California. *Middle:* Drilling for oil, Huntington Beach, California. *Bottom:* Oil wells at Summerland, California 484
334. Tipple of coal mine, eastern Kentucky 485
335. *Top:* General view of a coal mining camp, eastern Kentucky. *Bottom:* Street scene in a coal mining camp, eastern Kentucky . . 486
336. *Top:* The "million-dollar" tipple at Lynch, eastern Kentucky. *Bottom:* Miner's houses at Lynch, Kentucky 488
338. Part of the Hull-Rust-Mahoning open-pit iron mine, northeastern Minnesota 491
340. Howard Street, Hibbing, Minnesota 493
341. Hibbing High School and Junior College 493
342. Mechanized loading equipment of a U.S.S.R. coal mine . . 494
343. Kitwanga totem poles 498
345. Small fishing village on the west coast of Honshu . . . 501
346. "Fishermen's Wharf," San Francisco 503
347. *Top:* Taking salmon with a purse seine, Alaska. *Middle:* Brailing salmon from a trap, Alaska. *Bottom:* An Alaskan salmon cannery . 505
348. *Top:* Asari, a fishing village in western Hokkaido. *Bottom:* Fishermen's houses in Asari 507
349. Kettles for cooking fish, fish presses, and curing fish, Asari, Hokkaido . 508
350. *Top:* Typical Newfoundland homestead of the better sort. *Bottom:* A Newfoundland garden 509
351. Newfoundland coast line and fenced garden, with growing cabbages . 510
352. Waterfront at St. John's, Newfoundland 511
353. Transportation in Osaka, Japan 515

354. A Chinese wheelbarrow 516
355. Siberian hunters using reindeer as saddle animals . . . 517
356. Calling for the mail at Flingville, Kentucky 518
357. *Top:* Hokkaido carts. *Bottom:* A Japanese wagon, Kyoto . . 519
358. Road up Meatscaffold Creek, eastern Kentucky . . . 520
359. An unimproved road near Brookings, South Dakota, about 1904 . 521
360. The Pennsylvania Turnpike, at the Bedford Interchange . . 522
361. *Top:* Part of the Manhattan connection of the Triborough Bridge project. *Bottom:* East River Drive, New York City . . . 523
363. The old Chesapeake and Ohio Canal 525
364. A steel motorship, on the New York State Barge Canal . . 526
365. The "Atlantic" locomotive of 1832 527
366. *Top:* A modern streamlined train, the Capitol Limited. *Bottom:* A modern freight train with a load of coal 529
367. Three stages in the evolution of the modern automobile . . 531
368. *Top:* The lower end of Manhattan Island and the America, a modern ocean liner. *Bottom:* Freighters in the harbor at Tampa, Florida . 533
369. *Top:* A stratoliner. *Bottom:* A giant "war bird," the Boeing B-29 . 534
370. A jet-propelled fighter plane, the Lockheed P-80 B . . . 535
374. Pottery at Pottertown, western Kentucky 542
375. A Tampa cigar factory 544
377. Iron from the blast furnaces on its way to the steel mill, Zaporozhe, U.S.S.R. 548
380. Manitowoc, Wisconsin, plant of the Whitehouse Milk Company . 552
381. *Top:* A New Hampshire blanket mill. *Bottom:* Interior of a modern textile mill 553
382. *Top:* Rouge plant of the Ford Motor Company. *Bottom:* A blast furnace at the Rouge Plant of the Ford Motor Company . . 554
383. Final assembly line at the Rouge Plant of the Ford Motor Company 555
384. View of Portland, Oregon, with Mt. Hood in the distance . . 559
385. Main street of Amana, Iowa 561
386. Looking east across Nashville, Tennessee 563
387. The skyline of Boston, Massachusetts 563
388. San Francisco, California, and the bridges 564
389. Miami, on the Straits of Florida 565
390. The heart of Los Angeles, California 566
391. Revelstoke, British Columbia, on the Columbia River . . . 567
394. Three Kentucky towns built around the courthouse square . . 570
395. Karl Marx Street, Khabarovsk, Siberia 572
399. The skyline of lower Manhattan Island from Manhattan Bridge . 577
400. A rear view in midtown Manhattan, with the many storied Rockefeller Center in the background 578
401. Henry Hudson Parkway, New York City 579
402. Tall hotel buildings clustered around Central Park, New York City . 580

LIST OF MAPS AND CHARTS

Figure

1. The world with "four corners," by Cosmas Indicopleustes, 535 A.D. . 2
2. The Hereford world map, 1280 A.D. 3
3. Expansion of the known world by selected periods . . . 5
4. Actual and relative areas and populations of the continents . . 10
5. Distribution of the earth's inhabitants 12
6. Distribution of the total population of the United States in 1940 . 13
7. Distribution of the rural population of the United States in 1940. . 14
8. Distribution of the farm population of the United States in 1940 . 15
13. The "shrinking" United States 26
14. The general pattern of distribution of man's economic activities . 30
20. Population densities and patterns in one Oriental and three United States agricultural areas 36
23. Distribution of population in the Narragansett Bay area . . 39
24. Population trends in selected countries 43
25. Urban and rural population in the United States, 1790–1940 . . 46
26. Growth of United States population by regions . . . 48
45. Original timber regions of the United States 79
51. The dikes and polders of the Zuider Zee drainage project . . 84
54. Operating drainage projects in the United States . . . 87
58. Dust storms in the United States during April, 1935 . . . 93
60. Irrigation in the United States 96
68. Soil erosion in the United States 105
78. Average percentage of the possible hours of sunshine for the United States 115
79. Average frost-free season four years out of five for the United States . 116
80. Temperature efficiencies during the average frost-free season for the United States 117
82. A. Relative amounts of insolation from vertical and oblique rays of the sun. B. Curves of insolation and radiation for the 24-hour period of a day 120
83. A contrast in annual temperature ranges: Quito and Verkhoyansk . 121
84. Zoning of native vegetation and cultivated crops, resulting from elevation 122
85. January and July humidity for the United States . . . 127
86. Warm season evaporation in the United States . . . 128
87. Sling psychrometer 129
89. Distribution of dense fogs in the United States . . . 136

96. Areas of dense fogs for the world 136
97. Fifty-year rainfall record for Miles City, Montana . . . 143
98. Annual precipitation for the United States 144
99. Annual precipitation for the world 145
100. Diagrammatic representation of the general air circulation . . 149
101. Generalized January and July pressures and winds . . . 150
102. Summer and winter monsoons of southern Asia . . . 152
103. Diagrammatic representation of pressures and wind directions for high- and low-pressure areas 153
104. Regions of occurrence and paths of hurricanes and typhoons . . 155
105. New England hurricane, September 21, 1938 . . . 155
106. Frequency of occurrence of tornadoes in the United States . . 156
107. Weather maps for the day of the Louisville tornado . . . 157
108. Path of the Cleveland tornado of 1943 158
110. Diagram of a simple type of mercurial barometer . . . 162
111. Diagram of a cyclone, after Bjerknes 163
112. Paths of low-pressure areas in the United States . . . 164
113. Paths of high-pressure areas in the United States . . . 164
114. Occurrence of thunderstorms in the United States . . . 165
115. A weather map showing the location of the pressure areas and their relation to the "fronts" 166
117. Transition from solid rock to soil, where the soil is derived from residual material 175
118. Relation of the underlying rock to the overlying loose material in a glacial plain 175
121. Three stages in the formation of a peat bog in a shallow depression . 178
122. Soil groups of the world 180
123. Soil groups of the United States 181
126. Principal waterways of the United States 187
136. The New York State Barge Canal System 195
138. The port of Houston, Texas, and the Ship Canal . . . 197
142. The Tennessee Valley and the dams of the Tennessee Valley Authority 205
143. Natural runoff of the Tennessee River at Chickamauga Dam . . 206
145. The Missouri Valley and the areas which would be affected by proposed improvement 208
147. Section of the Arizona wall of the Canyon of the Colorado River at Hoover Dam 210
148. Columbia Basin or Coulee Dam project 211
154. Federal irrigation projects west of the 100th meridian . . . 219
155. Irrigation projects in the Colorado River Basin . . . 220
156. The Imperial Valley, its canals and irrigation districts . . . 221
158. The Central Valley project, California 223
159. Drive well in glacial drift 229
162. An artesian well 231
165. Average hardness of surface- and ground-water supplies in the United States 235
176. Relation of ground water to lake level 248
177. Topography of a portion of the Atlantic Coastal Plain . . . 252
181. Topography of the alluvial plains of the Little and Mississippi rivers . 256

184. Topography of a glacial plain area 261
189. Topography of a lacustrine plain 264
191. Topography of a degradational plain 266
195. Topography of a low plateau 273
196. Topography of a high plateau 275
197. Topography of a dissected plateau 277
202. Topography of a glaciated upland 281
206. Mountain topography 284
212. Principal iron-ore deposits of the world 293
213. Occurrence of coal, and coal mines, in glacial plains, dissected plateaus, and mountain areas 296
214. Coal resources of the world 297
215. Coal fields of the United States 297
216. Structural conditions favorable for the accumulation of petroleum . 299
217. Oil fields of the United States 300
218. *Top:* Proportion of the ocean at various depths. *Bottom:* Cross section of the land masses and oceans along the equator . . . 309
219. Cause of the tides 311
220. The ocean currents of the world 312
221. An irregular coast line resulting from depression of a hilly area on the coast of Maine 314
222. A smooth coast line resulting from uplift on the coast of California . 315
223. The harbor of Norfolk, Virginia, formed by local submergence . 316
224. San Francisco Bay, formed by local submergence . . . 317
225. The harbor and port of Seattle, Washington 318
229. Distribution of plant communities for the world . . . 326
230. Distribution of plant communities in the United States . . 327
248. The Land and Water hemispheres 350
249. A contrast in population concentrations resulting from differences in relative location 352
251. A British "life line" 353
252. The "keys" to the Caribbean 354
253. Warren County, Tennessee, and Gratiot County, Michigan . . 355
254. Two attenuated states: California and Tennessee . . . 356
255. Two attenuated countries: Chile and Canada 358
256. Range of county and state size in the United States . . . 359
257. Comparative size of selected countries 360
258. Distribution of the Eskimo, and the home of the Polar Eskimo . 365
263. The Kalahari country, the home of the Bushmen . . . 370
267. The homeland of the African Pygmy 375
270. The homeland of the Kirghiz 381
273. The Navajo country of southwestern United States . . . 385
277. Nomadic and commercial grazing areas of the world . . . 389
280. The homeland of the Fang 399
281. The homeland of the Djuka 402
286. The Hopi country of Arizona 407
290. Regions of Oriental agriculture 414
302. Distribution of types of Occidental agriculture . . . 431

314. Distribution of plantation agriculture 448
322. The Lower Amazon basin and Fordlandia 459
337. The Iron Ranges of Minnesota 490
339. Hibbing, Minnesota, and the iron mines 492
344. The important fishing grounds of the world 500
362. A proposed express highway system for the United States . . 524
371. Present and proposed routes of the overseas "merchant marine" of the air of the United States 536
372. A graphic representation of the shrinkage of the world with improvement of transportation 537
373. Ocean trade routes 541
376. Major industrial areas of Europe 548
378. Major industrial areas of Asia 549
379. Major industrial areas of the United States 551
392. Washington, D.C., about 1800 568
393. Boston, Massachusetts, 1775 569
396. Three classes of urban centers in the United States . . . 573
397. The city of New York in 1776 574
398. The city of New York in 1940 575
403. Map chart of the Marshall islanders of the Pacific . . . 592
404. The world according to Herodotus, 450 B.C. 593
405. The world according to Eratosthenes, 200 B.C. . . . 593
406. The world according to Ptolemy, 150 A.D. 594
407. Portolano chart of the Mediterranean, 1500 A.D. . . . 595
408. Mercator map of the world, 1569 A.D. 595
409. The world as mapped about 1800 A.D. 596
410. Types of maps available in various parts of the world . . 596
411. Areas for which sheets of the International Map of the World are available 597
412. Cylindrical equal-area projection and its construction . . . 600
413. Gall's stereographic projection and its construction . . . 600
414. Mercator's projection 601
415. Molweide's homolographic projection 602
416. Aithoff's projection 603
417. Goode's interrupted homolosine projection 603
418. North Polar azimuthal equidistant projection 604
419. North Polar gnomonic projection 605
420. Orthographic projection and its construction 606
421. Sinusoidal projection and its construction 607
422. Lambert's equal-area azimuthal projection and its construction . 608
423. Conic projection and its construction 609
424. Alber's equal-area conic projection with two standard parallels . 609
425. Polyconic projection of the United States 610
426. Antipodal areas of the world 612
427. The variable value of a degree of latitude 614
428. A series of maps to show the effect of enlargement and reduction on map scale 616
429. Isogonic chart for the world 618

430. Isogonic chart for the United States 619
431. Sketch of a land mass and a topographic map of the same area . 622
432. Irregular boundaries in eastern Massachusetts, with survey by metes and bounds 624
433. Land survey in the United States 625
434. Average length of the daylight period in the latitudes of the United States 628
435. Positions of the earth and sun at the times of the equinoxes and solstices 629
436. Standard time belts of the United States 633
437. Standard time belts of the world and the International Date Line . 634
438. Climatic types of the Americas and adjacent lands . . . 638
439. Climatic types of the lands of the Eastern Hemisphere . . 639
440. Climatic graph for the *Af* climate, Belèm, Brazil . . . 640
441. Climatic graph for the *Aw* climate, Bombay, India . . . 640
442. Climatic graph for the *Cfa* climate, Tokyo, Japan . . . 641
443. Climatic graph for the *Cw* climate, Hanoi, French Indo-China . 642
444. Climatic graph for the *Cs* climate, Athens, Greece . . . 642
445. Climatic graph for the *Cfb* climate, Paris, France . . . 643
446. Climatic graph for the *Dfa(b)* climate, Moskva, Russia . . 644
447. Climatic graph for the *Dwa(b)* climate, Harbin, Manchuria . . 644
448. Climatic graph for the *Dfc* climate, Tomsk, Siberia . . 645
449. Climatic graph for the *Dwc* climate, Okhotsk, Siberia . . 645
450. Climatic graph for the *ET* climate, Vardö, Norway . . . 646
451. Climatic graph for the *EF* climate, Framheim (Little America), Antarctica 647
452. Climatic graph for the *BS* climate, Urga, Mongolia . . . 648
453. Climatic graph for the *BW* climate, Iquique, Chile . . . 649
454. Climatic graph for an *H* or Highland climate, Quito, Ecuador . 649
455. Station model for the weather map 652
456. Four days of summer weather in the United States . . . 654
457. Profiles of the pedalfers 658
458. Profiles of the pedocals 661
459. Major physical subdivisions of the United States . . . 662
460. Glaciation in the United States 663
461. Principal rural land uses in the United States 664
462. Agricultural regions of the United States 664
463. Average summer temperatures for the United States . . . 667
464. Average winter temperatures for the United States . . . 668
465. Average winter sunshine for the United States . . . 668
466. Average length of the frost-free season for the United States . . 669
467. Average dates of the last killing frosts in spring for the United States 669
468. Average dates for the first killing frost in fall for the United States . 670
469. Amount of summer precipitation in the United States . . 670
470. Amount of winter precipitation in the United States . . . 671
471. Percentage of the total precipitation occurring during December, January, and February in the United States 671

472. Percentage of the total precipitation occurring during April to September inclusive in the United States 672
473. Percentage of the total precipitation occurring during June, July, and August in the United States 672
474. Average annual snowfall for the United States 673
475. Thermometer graduated in Fahrenheit and Centigrade scales . . 674

PART ONE. INTRODUCTION

Chapter One

THE GROWTH OF GEOGRAPHIC KNOWLEDGE AND THE FIELD OF GEOGRAPHY

Geography a Subdivision of the Field of Human Knowledge. With man's advance from the primitive stage of development of his earliest existence, the scope of his interests widened and the sum total of his information increased correspondingly, eventually to the extent that some division of the field of human knowledge became desirable. Geography is the one of these subdivisions having as its field the systematic study of the earth's surficial features and their mutual relationships. Included as subjects of this study are the observable aspects of both the organic and inorganic worlds, considered with special reference to their varied spatial arrangements and interrelationships, and particularly as they affect man and his works.

Geography an Old Subject. Acquisition of knowledge of the home area and inquiry about what lies over the immediate horizon have always enlisted human interest. Thus the study of geography, recognizable as we know the subject today, was prosecuted as far back in the past as we have any record; probably its rudimentary beginnings were even earlier.

Early Beliefs as to the Shape and Size of the Earth. Man began to speculate about the shape and size of the earth at a very early date, advancing theories in accordance with the facts then known. All of these earliest concepts of the shape of the earth were based upon the idea that the homeland was the center of the world, and all were much alike. Thus the Babylonians conceived of the earth as the flat, circular floor of a great dome, the sky, resting on foundations beyond the oceans which surrounded the inhabited lands. The view held in Egypt was similar, except that the floor was thought to be oblong, with Egypt rather than Babylon at its center. Not until the sixth century before Christ was the earth mapped except as a plane of small extent, since the limited areas known previously made a small, flat earth seem logical.

Early Beliefs as to the Extent of the Inhabited World. Until the development of Greek civilization, and even for some time thereafter, there was but little exact knowledge of the earth's surface among white populations, except of the lands which bordered the eastern Mediterranean, around which the earliest civilizations of the Western world developed, though accounts of far distant areas to the north, south, east, and west, based on hearsay, were in circulation. Most descriptions of these faraway lands must have been transmitted orally and, in passing from narrator to narrator and from one language to another, they often suffered material alteration. This may explain in part the fantastic ideas current in earlier times as to conditions and customs in distant regions.

Greek Concepts of the Shape and Size of the Earth. By the beginning of the sixth century before Christ, the world known to the Greeks extended from the Black Sea to the western end of the Mediterranean, and considerable distances to its north and south. The numerous observations and increasing knowledge of facts in these widely separated areas led to further consideration and more logical theories as to the shape of the earth, succeeded somewhat later by measurements of its size, remarkable for their accuracy at that early period of human history.

Very early in the fourth century before Christ, the hypothesis of a spherical earth, based on philosophical considerations, had been advanced and, shortly thereafter, the theory that the earth rotates on its axis had been proposed, though

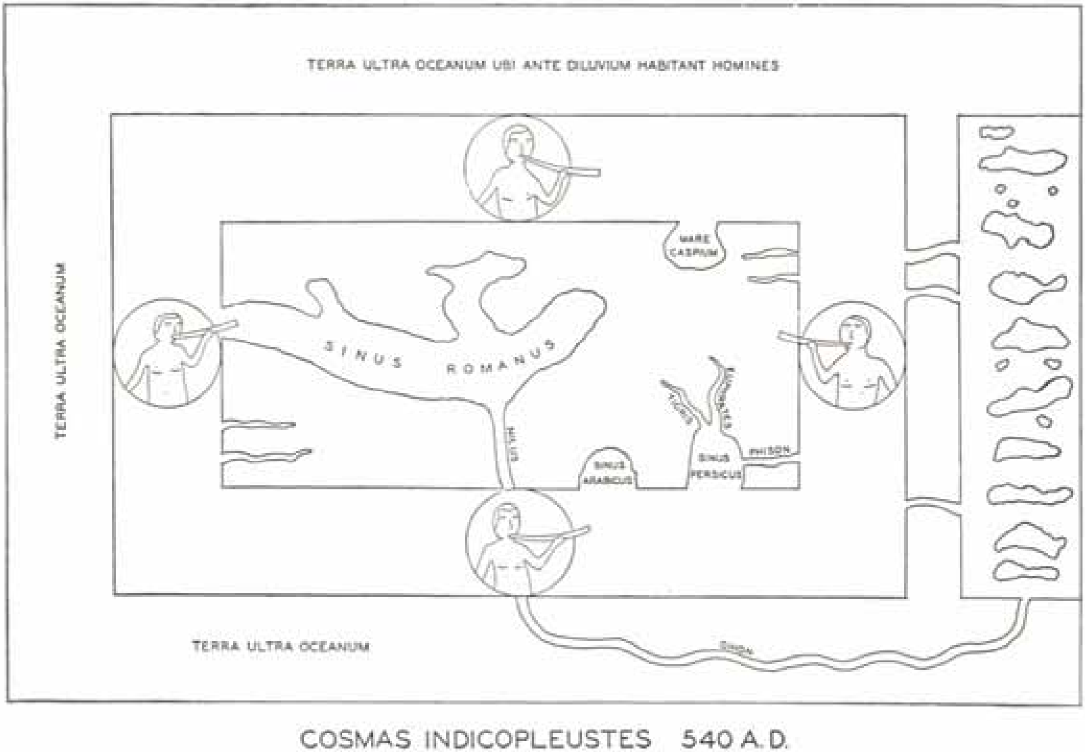

FIG. 1. The world with "four corners," by Cosmas Indicopleustes. (After Times Atlas.)

neither received wide acceptance immediately. By 350 B.C., additional observations enabled Aristotle to formulate arguments which established the earth's sphericity as a fact; to determine the obliquity of its axis; and to compute the value of the earth's circumference as 45,000 miles. By the close of the century, Greek philosophers, though not the common people, held essentially present-day views concerning the shape of the earth and its relation to the solar system.

By the third century before Christ, the great library at Alexandria, founded by Ptolemy I, had become an important center for research in mathematical geography under the leadership of Eratosthenes, the chief librarian. He calculated the known, inhabited world, which he mapped, to have an east-west extent of 9000 miles and a north-south extent of 4400 miles. He also measured the circumference of the earth and, basing his determination of the value of a degree of latitude upon the distance between Syene and Alexandria as determined by the older Egyptian land surveys, secured a result which was in error only 14 per cent. This error may seem large today, but considering the stage of advancement of human knowledge at that early date, the measurement was remarkably accurate and not bettered for hundreds of years thereafter.

The Dark Ages of Geography. From the second century after Christ until well into the Medieval period was a time of intellectual stagnation. Even before the decline of the Roman Empire, progress in geography ceased, not to be resumed for several hundred years. Worse, not only was progress arrested, but actual retrogression occurred. The doctrine of a spherical earth was rejected by all except a few scholars, reluctant to voice their views, and in its place was substituted the flat-earth theory which had always prevailed as the popular concept. The authors of maps of the world, nearly all of whom were monks, delineated the earth as oblong, circular, or elliptical in shape, surrounded on all sides by oceans. Palestine, or the Holy Land, was generally given a central location on such maps. These shapes represented attempts to reconcile the maps with such expressions in the Bible as "the four corners of the earth" (Isa. xi:12), and

"the circle of the earth" (Isa. xl:22); the elliptical shape was a compromise.

Christian Cosmography. Christian cosmography reached its extreme development under the leadership of such men as Cosmas of Alexandria, a monk who lived during the sixth century after Christ. He taught that the earth was flat, oblong in shape, and surrounded by oceans, beyond which lay Paradise. He believed that the sun, which he assumed to be small in size and near the earth, revolved around a high conical mountain to the north, so that the sun's light was cut off part of each 24-hour day. This caused night. He thought that short summer nights resulted from the sun's revolution around the top; long winter nights from revolution around the base of the mountain. He taught that the dome of the heavens covered the earth, resting on its edges, and that all was supported by the "stability of God." Under such leadership and teaching, it is not surprising that ignorance was the rule, that superstition flourished, and that no advances

FIG. 2. Hereford world map. To orient this map, it should be turned, since the top, showing Paradise is east. (After Times Atlas.)

in geographic knowledge were made. These were in truth the "Dark Ages" for geography.

The Renaissance of Geography. With rapidly increasing knowledge of the earth and its surface, particularly during the period of exploration, the untenable theory of a flat earth lost in popularity. Later, the incapability of its satisfactory defense was recognized so generally that the idea of a spherical earth again received acceptance, not only by scholars but by the common people as well. Modern times have witnessed increasing interest in measurements of the earth's surface, prompted by the continually expanding area known to man and the practical value of such knowledge. Today, however, though measurements are still being made by the great map-making bureaus of the civilized nations of the world to determine the exact configuration of the earth with greater accuracy, the results of such studies will not alter our present information materially, for we already know both the shape and size of the planet on which we live within very narrow limits of possible error. Among all civilized peoples, the spheroidal shape of the earth is accepted as a fact; only among primitive populations and the ignorant does the doctrine of a flat earth receive credence today. In similar fashion, the determined dimensions of the spheroidal earth are accepted without question by all competent to have an intelligent opinion.

The Early Known, Inhabited World. The early civilizations which established the foundations of geography in the Western world developed at the eastern end of the Mediterranean Sea. From this center, the known inhabited world expanded in all directions as travelers and merchants visited distant lands and returned to relate their experiences and write about their journeys. Among others, Hecataeus, who lived about 500 B.C., is credited with a "Periodus," or description of the world in two volumes: one for Europe, a second for Asia. Somewhat later, Herodotus (484–425 B.C.) visited Asia Minor, Greece, Persia, and the Black Sea country. In accounts of his travels, he distinguished between Africa and Asia as divided by the Red Sea, a new idea at that time, for previously the Nile River had been accepted as separating the two continents. He had also apparently heard of many rivers such as the Indus, and possibly of the Niger, but his ideas of them and of their courses were vague.

The campaigns of Alexander, from 334 B.C. to his death, added greatly to the total of geographic knowledge, both of areas to the north of the Black Sea and of Asia as far to the east as the Indus Valley. At the same time that Alexander was extending knowledge of the world to the east, Pytheas of Massilia, present-day Marseilles, was adding to knowledge of areas to the west of the Strait of Gibraltar. He visited Britain and, if he did not visit, he had at least heard of the Baltic countries. Thus, by the end of the second century before Christ, the lands bordering the Mediterranean Sea were known with some degree of exactness and Mediterranean populations had vague ideas of areas and peoples to the north, and of black men and pygmies to the south.

The Known World of the Period of the Roman Empire. During this period, the emphasis in geography was on the acquisition of facts concerning areas rather than in speculations as to the size and shape of the earth and its relation to the other members of the solar system. This was in accord with Roman interest in the practical rather than the theoretical. The outstanding figure in geography during this period was Strabo, who compiled a geographical encyclopedia, consisting of seventeen parts, of the then known world. This treatise dealt with Spain and Gaul, Italy, northern and eastern Europe, Greece, Asia Minor, Persia and India, the Tigris-Euphrates region, Syria, Arabia, the Far East, and Africa. From this it can be seen how greatly the known, inhabited world had expanded by this time. Knowledge of distant lands was, however, still inaccurate, for it was based largely on hearsay. This is illustrated by the maps of Ptolemy, who believed that Asia extended much farther to the east than is actually the case. This error in mapping persisted for hundred of years, later influencing Columbus in his belief that he had reached Asia rather than what we now know as the New World.

The Known, Inhabited World during the Medieval Period. During the Dark Ages, there was little addition to knowledge of the inhabited world. Much of what was written, indeed, represented only compilation or rearrangement of information acquired at a much earlier date. During this period, however, the old Roman trade routes remained open; Baltic amber from the north, gold and ivory from the south, and silk from the east, all luxuries, moved precariously and intermittently. The Mediterranean, as of old, was the

main east-west highway; overland routes were long, difficult, and hazardous.

Missionaries were active during this period. They visited Scandinavia and even reached Iceland. To the east, their activities extended to India by 189 A.D.; to Abyssinia by 300 A.D.; and to China by 600 A.D. During the long period to 1200 A.D., however, though much movement was going on, it did not add appreciably to acquaintance with the geography of the distant areas visited, either immediately or for many years thereafter, partly because of the lack of printed books until the fifteenth century.

The Crusades produced a great interest in both geographic facts and commerce. Rise of the power of the Church was accompanied by the sending of missions to eastern lands. Travelers, as the Polo brothers in the middle of the thirteenth century, added to the gradually growing store of information. Accounts of these travels by the younger Marco Polo, a son and nephew, written during the period 1298–99, described portions of central Asia not visited again for hundreds of years. Odoric, who reached Peiping in 1323, likewise contributed in an important way to the knowledge of eastern Asia.

During this period, Venice, Genoa, Marseilles, and many other cities were interested in eastern trade, carried on partly by overland routes. This led to acquaintance with the countries traversed by these highways of commerce. At the same time, sailors were, by the end of the thirteenth and early in the fourteenth century, extending knowledge of areas beyond the Strait of Gibraltar to the Azores, the Canary Islands, and Madeira.

Transmission of the information acquired was, however, still very slow and errors resulting from preservation of the Ptolemaic traditions persisted in the face of known facts, since it required half a century or more for the knowledge gained by travel to reach the map makers. Further, geographic fables and geographic facts were so inextricably interwoven that their separation was difficult, or even impossible. The legend of Prester John, which found general acceptance in Europe from the middle of the twelfth to the end of the thirteenth century, may serve as an illustration of this state of affairs. This fabulous Christian monarch of Asia was reputed to reign in an area where there were "no poor, no miseries, no dissension, no lies, and no vices." In his kingdom, the sands of the streams were gems; giant ants dug gold for the fortunate inhabitants; and, to add to the attractions, there was a Fountain of Youth.

The Expansion of the Known, Inhabited World during the Period of Discovery, and the Known World of Today. Early in the fifteenth century, Portuguese navigators and explorers began to assume an important place in the ranks of the contributors to the rapidly growing body of geographic information. Under the leadership and

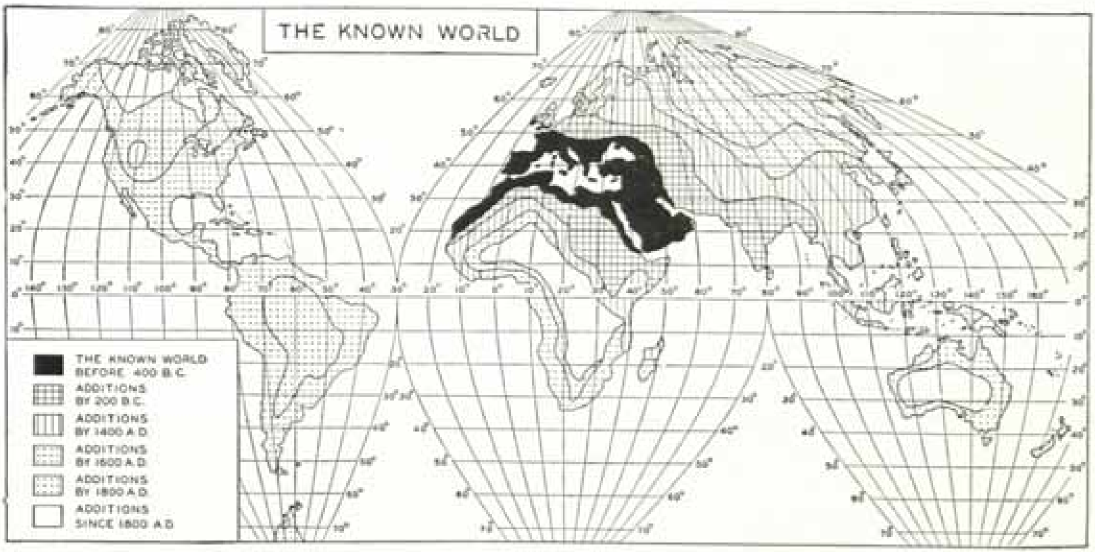

FIG. 3. This map shows the expansion of the known world by selected periods.

inspiration of Prince Henry the Navigator, exploration was pushed along the west coast of Africa, reaching the Congo River by 1482. By 1498, the Cape Route to India had been discovered by Vasco da Gama, who had sailed from Lisbon one year earlier. Even after this, the Ptolemaic beliefs as to the shape of India did not disappear completely, so slowly did knowledge diffuse at that time.

During this same period, Columbus reached the Bahamas, October 12, 1492, and, on subsequent voyages, Jamaica, Cuba, Trinidad, and the mainland of the Americas. He died, however, still believing that the lands he had discovered constituted a part of southeastern Asia, and of the islands off its coast. In fact, the true outlines of the New World were not revealed until early in the sixteenth century, Cabot, Balboa, Cortez, Pizarro, Magellan, and others contributing to this result. From that time down to the present date, we have been filling in the major outlines of the map of the world as revealed to us by these early explorers. Africa, Australia, South America, and the other continents today hold but few secrets; they have been explored and mapped in larger part. Only the polar areas and a few limited portions of certain continental and island interiors remain more or less unknown, and these unknown areas shrink in extent from year to year. Soon, detailed studies and mapping will be all that remain to be done to complete the undertaking of assembling data which will supply an adequate picture of the earth's surface.

The Historical Background of the Present Objectives and Fields of Geographic Study. Though the present extensive subdivision of the field of human knowledge did not exist during the period of the early civilizations which flourished around the margins of the Mediterranean, particularly at its eastern end where our geography had its beginnings, geographic inquiry was prosecuted then, much as it is today. Eratosthenes, with his measurements of the earth, may properly be considered a pioneer in the field of physical geography; Herodotus and Strabo, with their descriptions of the known, inhabited world as a series of regions, as contributors to regional geography; and Claudius Ptolemy, with his representation of the facts of area on maps of improved projection, as the initiator of methods of effective, graphic portrayal of geographic information. On this early foundation developed the geography of the nineteenth century, in which natural phenomena were studied as "natural history," later to be subdivided into various fields: botany, zoology, geology, and others, including geography. In this study, the older, largely descriptive method was amplified by ventures in systematic organization and the establishment of causal relationships, illustrated by Humboldt's *Cosmas*, a monumental description and attempted geographic synthesis of the known facts of the physical world and man, which appeared in several volumes between 1845 and 1859.

Following recognition of geography as a separate branch of inquiry, two distinct fields presented themselves: (1) study and classification of natural earth features, which developed as "physical geography"; and (2) organization of cultural features, or those resulting from the activities and works of man, in coherent patterns, from which what is sometimes known as "human geography" evolved. In reality, of course, there has never been any other kind of geography, "except in the minds of specialists," for not only does the natural environment impose limitations on man, but he is in turn an effective agent in modifying the limiting agency.

In the attempt to explain, or establish "relationships" between natural conditions, human activities, and other facts as manifested in observable form in the landscape as modified by man, undue emphasis was placed on the importance of "relationships." Therefore these two subdivisions of the subject diverged from one another more and more, and both diverged from the idea that geography is concerned with area. On the one hand, Physical Geography became increasingly a study of forces producing material features such as land forms; Human Geography primarily a search for "relationships" between the natural environment, human activities, and the material manifestation of their results, or an attempt to establish environmental control as their basis.

Present-day Geography. Shortly after the beginning of the present century, this illogical and unfortunate development of the subject lost in popularity and, of late, geography has become more and more concerned with giving identity to areas, no two of which are exactly alike, in attempting to make them real. This is a logical objective, as geographic inquiry is properly associated with space and place, with units of the

earth's surface or "areas," mostly inhabited, and with the populations as essential a part of the areas as are their other features. Geography is thus a body of organized facts related to definite places and concerned with the adjustments between population groups and the regions where they live, or a study of the earth and man. This delimitation of the subject is sanctioned by long usage; it is implicit in the name of the subject itself which, derived from two Greek words, means "description of the earth." Geography is not, however, a study of all facts which find areal expression, but only of those of "observable" material expression, and particularly of those which limit man and his present and potential activities; and of those which find expression in forms resulting from man's impress on an area. For example, a study of rail lines lies within the field of geography; one of rail rates as such does not. However, consideration of rail rates as they affect crop systems, or any other observable material feature of an area, is within the field of geographic inquiry.

Geography is thus in all its phases a study of regions: either a study of certain regional aspects or a unified study of all, within the limitations stated previously. Studies of limited scope give rise to special fields of geography; if of production, to economic geography; if of those aspects which affect international relations, to political geography; if the geography of past periods is the subject of study, to historical geography. Other special fields are limited similarly. If, however, the study involves consideration of all the observable material aspects of the natural and cultural environments in their varied interrelationships, it is regional geography.

Such regional study: describing, explaining, and evaluating the actualities and potentialities of the observable material features of areas in their complex interrelationships, is the culmination of all geographic inquiry. In the final analysis, therefore, the field of geographic study is the face of the earth, with special reference to areal differentiation, that is, the varied spatial arrangements and interrelationships of the facts of area. In the following chapters, we shall proceed to inquire as to some of the ways in which this differentiation manifests itself and some of the causes for these striking differences in areas.

QUESTIONS AND EXERCISES

1. Why did expansion of the field of human knowledge render its subdivision desirable?
2. Locate Babylon and Egypt on a map. Why did the Egyptian belief as to the shape of the earth differ from the Babylonian?
3. What "fantastic ideas" as to conditions in distant areas were current during the earlier periods of history?
4. What evidence have we that the earth is roughly spherical in shape?
5. Who was Herodotus? When and where did he live and with what fields of knowledge is his name associated?
6. Where did the earliest civilizations of the Western world develop? Why was this region particularly favorable for the development of civilizations at an early date?
7. Why is the Nile River a poor division between Africa and Asia? Locate the Indus and Niger rivers on a map.
8. How did the Ptolemaic maps influence Columbus in his belief that he had reached India rather than discovered a New World?
9. What is amber? Why was it an item of trade during the Dark Ages?
10. Why did the lack of printed books prevent rapid diffusion of geographic knowledge? When did printed books appear?
11. Who was Marco Polo? What countries did he visit and when did he visit them?
12. What Mediterranean cities were important in the trade with the East during the Medieval period? Locate these cities on a map and explain how their location enabled them to function in this trade.
13. Who was Prester John and what is the legend associated with his name?
14. How many voyages did Columbus make to the New World? What areas did he visit on these voyages?
15. Report on the explorations of Cabot, Balboa, and Magellan.
16. What continents and large islands still remain unexplored and unmapped in part?
17. What did "natural history" formerly include? Why was geography a logical part of the subject?
18. With recognition of geography as a separate subject, into what two fields was investigation divided? How and why did these two fields di-

verge from one another, and in what respects did both diverge from the earlier field of the subject?

19. What is the field of present-day geographic inquiry? With what types of facts does geography deal? What is "economic geography"? "Political geography"?

20. Why is regional geography the culminating aspect of all geographic inquiry?

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Bowman, Isaiah, *Geography in Relation to the Social Sciences*, Charles Scribner's Sons, New York, 1934.

This reference supplies an excellent discussion of the field of geography and its position among the social sciences, as indicated by the title.

Dickinson, R. E., and Howarth, O. J. R., *The Making of Geography*, Oxford University Press, New York, 1933, Chaps. I–XIV.

These chapters trace the development of geography from the period of the early civilizations of the Near East down to the present day in some detail.

PART TWO. MAN: HIS DISTRIBUTION AND NUMBERS

Chapter Two

MAN: HIS NUMBERS AND DISTRIBUTION

Distribution of the World's Population. One of the most obvious manifestations of areal differentiation is afforded by the uneven distribution of the earth's inhabitants, nearly 95 per cent of whom live in the so-called "people's hemisphere." This is the half of the earth's surface centered around a point in the French-Italian Alps. One reason for such a concentration of population on this 50 per cent of the earth's surface will be apparent after examination of Fig. 248, for it is essentially the land hemisphere.

In addition to this aggregation of population, related at least in part to the distribution of land and water, there are other and possibly even more striking concentrations of the world's inhabitants, at present believed to number approximately 2,250,000,000. This is about 40 persons to the square mile of land surface, or approximately 90 per cent of the average number per square mile for the United States in 1940. But, though this average is relatively low, population densities in limited areas are high; for 50 per cent of the earth's inhabitants live on less than one-tenth, and 65 per cent, on one-seventh of its land surface.

Thus the continent of Asia, with its western peninsula-like extension, the continent of Europe, though comprising but slightly more than one-third of the earth's land surface, is today the home of at least 75 per cent of the world's people. Within this area, also, population densities vary greatly. For example, central Asia, sometimes known as the "dead heart" of the continent, and the frozen north bordering the polar seas, are sparsely settled. By contrast, China, India, and Japan have nearly 1,000,000,000 inhabitants, or almost one-half of the world's total population.

Differing from these densely occupied areas, all north of the equator, the lands of the Southern Hemisphere have relatively few inhabitants: less than 10 per cent of the number for the entire world. Australia, the only continent other than uninhabited, ice-buried Antarctica lying entirely south of the equator, has about the population of prewar Tokyo, Japan. South America, both north and south of the equator, supports only a few millions more than do the four main islands of Japan; Africa, south of the equator, less than half as many as does that Island Empire. All the land masses of the Southern Hemisphere combined are the home of only about one-quarter of the probable number living in China alone.

Of all the lands of the Southern Hemisphere, indeed, only Java is densely populated. This island, with an area slightly more than 90 per cent of that of Iowa, today supports nearly 50,000,000 people, an increase of 1000 per cent over the number in 1800. In this human anthill the average population density is almost 1000 persons to the square mile, approximately 22 times that of Iowa, a very productive agricultural area. Further, numbers continue to grow with disturbing rapidity.

When the world's present population is studied, it is apparent that two outstanding facts are its very uneven distribution, and its concentration in areas north of the equator, especially marked in eastern and southeastern Asia. A third is that rates of increase vary from area to area, sometimes even more greatly than do present densities. Such great differences in man's distribution and rates of increase must be more than accidental.

The Period of Man's Occupancy of the Earth. All investigations indicate that many generations of man have inhabited the earth. This is true even for those areas which are sparsely occupied at present, as well as for others where natural oppor-

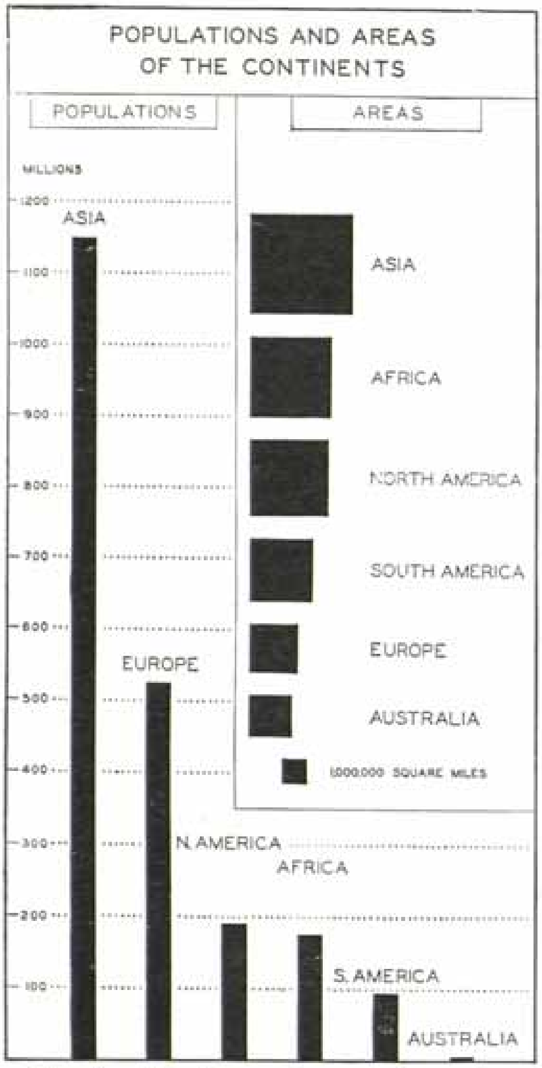

FIG. 4. This diagram shows both actual and relative areas and the populations of the continents. Note particularly the great difference between the populations of Europe and Australia by contrast with the comparatively small difference in their areas.

tunity is greater and populations are denser. Though the probable time has been fixed approximately, the available record is so incomplete we are still uncertain exactly when and where man first established himself. Certain it is, however, that the period of his existence for which we have no documentary evidence is many times the length of that for which we have such a record.

In fact, his first appearance occurred so long before the dawn of history that our knowledge of man of those long bygone times must be obtained from his skeletal remains and implements, and the bones of the animals with which these remains are found in caves or gravels and other loose deposits in which they have been preserved. From a study of these, we know something of how he lived, and that prehistoric man inhabited the earth at least as early as the Ice Age.

Areas Where Man First Established Himself. In speculating as to what parts of the earth's surface were possible of human occupation during the earliest stages of man's existence, it is obvious that certain areas should be excluded from serious consideration. It is improbable, for example, that the colder polar regions were the home of man during the long period of time when he had no adequate means of protection from low temperatures. Similarly, others of extreme aridity, and those of the hot, humid, densely forested tropics presented conditions with which it is unlikely he could cope effectively early in the life of the human race.

This limits the probable places of his origin to the widely dispersed tracts of grassland and relatively open forest which lie between the almost impenetrable forests of the rainy tropics and the frozen wastes near the poles. In fact, it is in such regions that the remains, implements, and traces of the activities of very early man have been discovered. From these areas, he has today spread to practically all parts of the earth's land surface, as progress has made it possible for him to meet the more adverse conditions of less favored locations successfully.

Areas Where Man Has Today Established Himself. Nature imposes difficult but not impassable barriers to the spread of advanced populations. No longer do high mountains or wide expanses of ocean water prevent man's movement from one part of the earth's surface to another, as they did until rather recently. Neither do low temperatures, scanty or excessive rainfall, or other unfavorable environmental conditions preclude the possibility of his occupation of an area, as they did in the remote past. Today, as a result of this development, man, by contrast with a given species of plant or animal life, is ubiquitous; he is found almost everywhere on the earth's surface where land appears.

If there is water, or the possibility of securing it, he commonly makes use of this opportunity to practice agriculture, even in desert regions.

He likewise makes his home in the higher latitudes, or near the poles, where the land is exposed, though often forced to turn to the sea for most of his food supply and to satisfy other needs. In the higher altitudes as well, he occupies areas free from permanent snow and ice cover, if slopes are not impossibly steep. High plateaus were even preferred as locations for the early Indian civilizations of the tropical Americas, where the oppressive heat and humidity of the adjacent lowlands, and their dense and luxuriant vegetation, impose handicaps difficult to overcome. In the higher latitudes, or nearer the poles, however, occupation of highland areas offers less attraction, and is frequently intermittent, being confined to those months of the year when the snow cover disappears with the coming of summer.

Man has at last, many centuries after his first appearance on the earth's surface, succeeded in establishing himself in many places where natural opportunity is relatively limited, and even where conditions are so unattractive that it is difficult to understand his presence, unless under compulsion. Except for regions of shifting sand in the driest of deserts, limited areas of steep slopes or bare rock, perpetually ice-covered lands near the poles, and snow-covered high mountains, practically all parts of the earth's land surface today support populations of varying degrees of density.

Origin of the Present Distribution of Population. Though it is true that man has finally spread to virtually all parts of the earth's land surface, his distribution is still very uneven and sometimes rather difficult to explain. Inspection of the accompanying map, Fig. 5, will disclose several densely populated areas, each surrounded by extensive, much more sparsely inhabited belts. These areas with dense populations are of relatively limited size, widely scattered, and separated by considerable distances, with densities in the bordering belts decreasing with varying degrees of rapidity.

The fact there are a number of such population concentrations, in association with their dispersal, suggests that diffusion probably did not occur from one, but from several centers, with the degree and extent of the spread from a given center related to the attraction of bordering areas. In some cases, this desirability of the centers from which diffusion occurred resulted from climatic and topographic conditions; in others, it may have derived from additional factors as well, particularly within recent times. Whatever it may have been, the initial attraction which afforded opportunity to man was enhanced by the activities of the first human occupants, so that the nuclear characteristics were intensified and successive accretions or additions of population occurred. Thus the present distribution of mankind indicates not only those portions of the earth's surface where the original opportunity afforded by nature was great, but the end product of population growth, induced by natural advantages, plus their modification by man's activities.

The World's Total Population: Past and Present. The total number of the earth's inhabitants at present is not known definitely. This is because accurate enumerations are lacking for many areas. Estimates of the numbers for earlier periods are even less reliable, being only rough approximations based in considerable part on probable densities associated with the stage of development and economic activities.

Censuses were taken during early times, it is true, but these were for special purposes, such as determining the number of men available for military service, or those subject to taxation. Such partial enumerations afford unsatisfactory data for estimating total population. Because of an inadequate basis, therefore, estimates of the world's total population during the earlier periods of the past are at best only intelligent guesses.

Not until about 1800 was knowledge of the total number of inhabitants reasonably accurate, even for limited areas, for, prior to that time, there was much opposition to counting the people. Thus, when an enumeration was proposed for Great Britain in 1753, many argued that it would be an invasion of personal liberty, and that it would likewise expose national weakness. By the end of the nineteenth century, however, trustworthy censuses were available for most parts of the world with white populations. Similar enumerations had likewise been made for India by 1901, and for Japan by 1920. Nevertheless, the population of China, probably almost 25 per cent of the world's total, is still known only approximately. The same is true for the populations of several other areas. This is unfortunate, for, if we knew the numbers of the world's inhabitants, present and past, and their distribution over a long period of time, we would possess information of great interest and value.

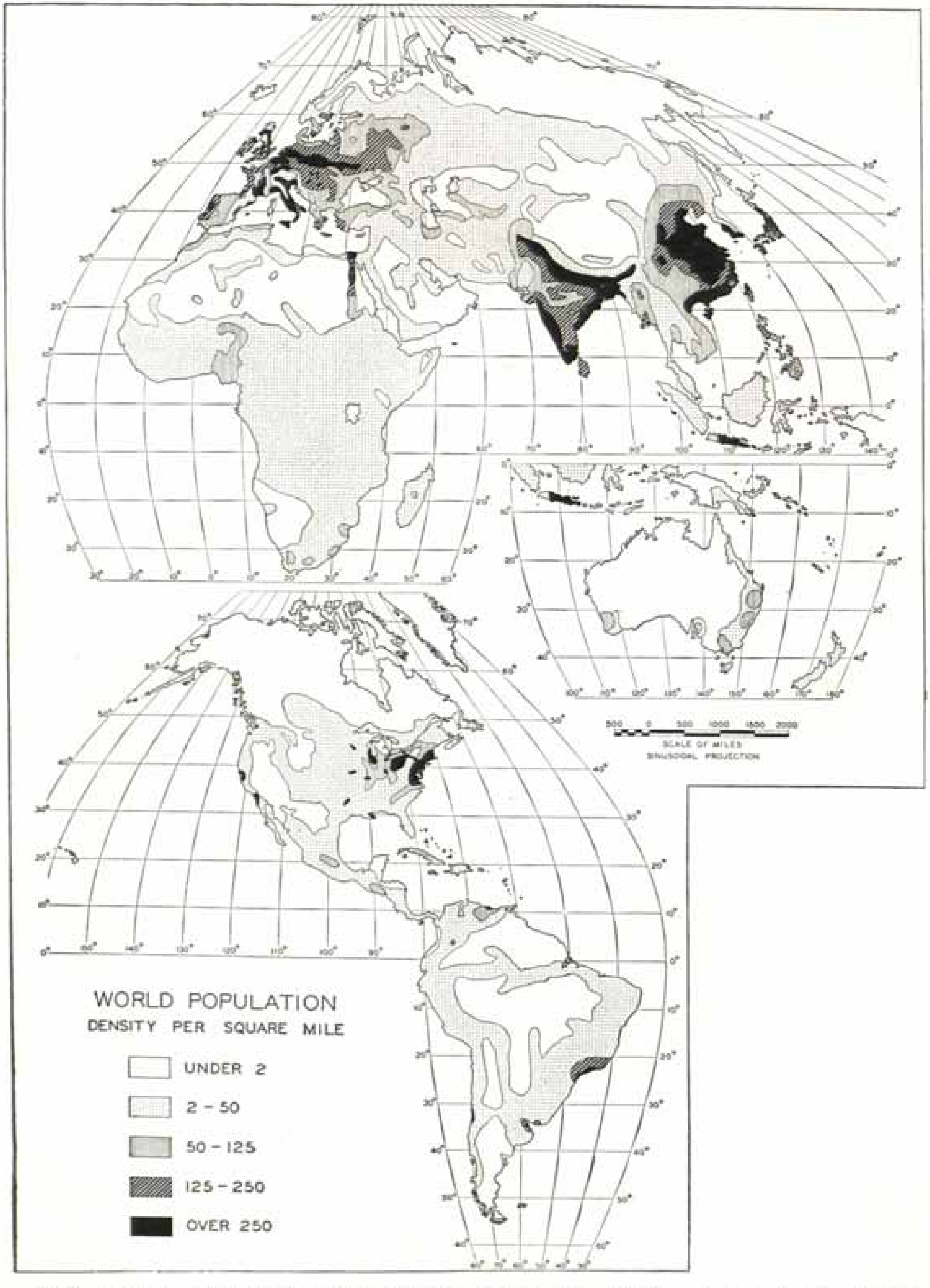

FIG. 5. This map shows nuclei of dense population surrounded by extensive, much more sparsely inhabited areas. In the New World these nuclei are of comparatively recent origin.

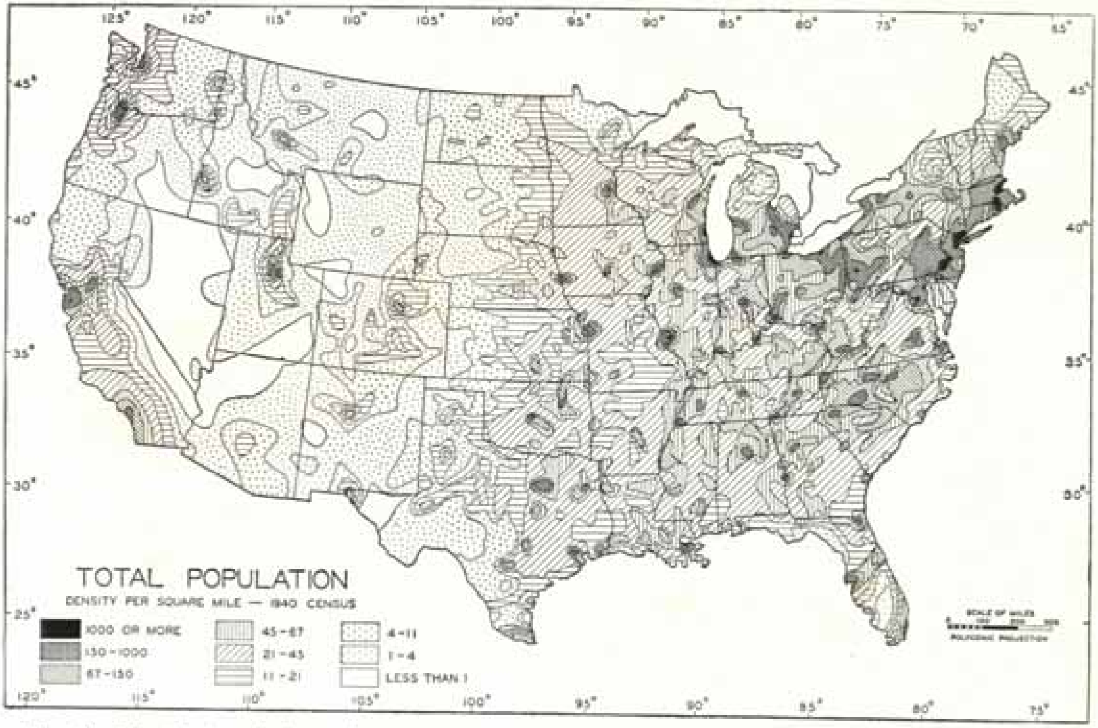

FIG. 6. Distribution of the total population of the United States in 1940. This map shows that: (1) there is great variation in population density from area to area; (2) the eastern half of the United States is more densely populated than the western; and (3) there is greater variation in population density in the eastern than in the western half of the country.

In the eastern half of the United States, the densely populated areas are good agricultural regions such as the Mississippi Valley, or those where commerce or industry, or both, are highly developed. Areas with sparse populations in this part of the country include the cutover lands of the Lake States and elsewhere, rough country such as parts of the Appalachians and Ozarks, and poorly drained areas, some of which are salt marshes and swamps, like those of Florida.

The dense populations of the western half of the United States are in the Valley of California and adjacent areas, the Willamette Valley of Oregon, and the Puget Sound region of Washington. These are all lowlands. There is also one other area which supports many inhabitants. This is the Salt Lake Oasis. By contrast with these four regions, the Great Basin, the Rockies of Idaho, western Texas, and the Nebraska Sand Hills are sparsely inhabited. (Courtesy of J. W. Alexander, G. A. Zahorchak, and the *Geographical Review*, Population Density Maps of the United States: Techniques and Patterns, New York, 1943.)

However, even though the present fragmentary data do not cover more than 60 per cent of the world's inhabitants with any great degree of accuracy, an estimate of the world's total population as approximately 2,250,000,000 is probably not far from correct.

Present Location of Densely Populated Areas. There are today three relatively large areas where population densities are far above the average. These are: (1) eastern and southeastern Asia; (2) western Europe; and (3) northeastern United States and adjacent parts of Canada. In addition, there are several others, such as the Nile Valley, of more limited areal extent. In western Europe and northeastern United States, the support of large numbers is made possible by comparatively recent and extensive industrial development. In eastern and southeastern Asia, and in the Nile Valley as well, however, agriculture is still the principal economic activity.

Present Location of Sparsely Populated Areas. By contrast with such densely populated areas in Asia, Europe, and North America, other parts of the earth's land surface often have but few inhabitants. Study of the map, Fig. 5, will show that this is true in all latitudes, or at all distances from the equator. Near the poles, continuously low temperatures limit opportunity too greatly

to permit of many inhabitants; in the hot and humid tropics, conditions are likewise unfavorable for the support of large numbers. Elsewhere, either aridity or excessive precipitation, or high altitudes and low temperatures, are deterrents to human occupancy. These same factors which operate to limit the number of inhabitants in large areas are likewise effective locally in others which are smaller and in general densely populated. Thus, in India, with a population probably now in excess of 400,000,000, and densities in limited areas of Bengal of 2000 or more per square mile in purely agricultural areas, the number of persons to the square mile drops to 157 in the northeast, in Assam, where rainfall is excessive; and to 9 in the northwest, in Baluchistan, where it is too dry. Though such variations are understandable, there are many anomalies or peculiarities of popu-

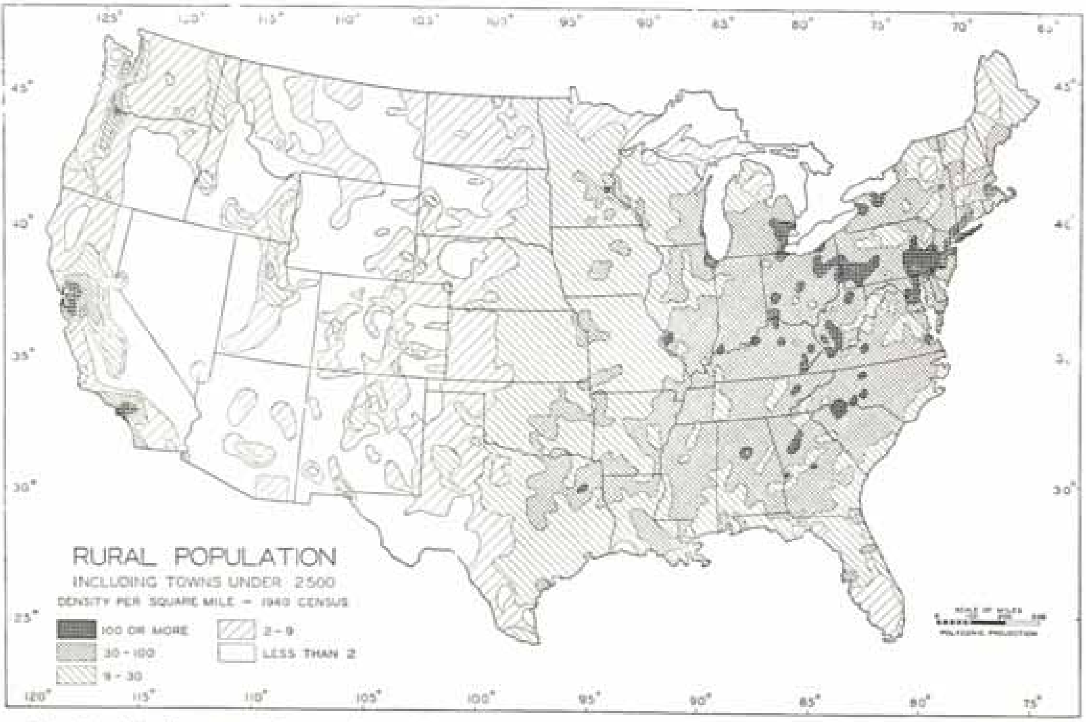

FIG. 7. Distribution of the rural population of the United States in 1940. This map shows the distribution of all persons living on farms, in unincorporated places, and in all population aggregations with less than 2500 inhabitants. It will be observed that rural, like total population, is much denser in eastern than in western United States, except locally in limited areas of the West.

In the more densely populated eastern half of the country, characterized by population belts with north-south trends, the areas with sparse rural populations are in general those with unfavorable topography, and often unproductive soils as well, for rainfall is everywhere ample, being 20 inches or more. Densities above the average may represent suburban development, as in the Chicago area; or mining camps, as in parts of eastern Kentucky. In the northern portion of the more densely populated eastern half of the United States, part of the seemingly large rural population lives in small towns, too small to be counted as urban centers because they have fewer than 2500 inhabitants. In the southern portion of this same eastern half of the United States, however, most of the rural population actually lives on farms, for this part of the country has a dense farm population by comparison with other parts of the United States.

To the west of the more densely populated agricultural regions of the eastern United States, there is a transition zone, where extensive grain farming and grazing of livestock on large landholdings support the population, except in limited areas under irrigation. To the west of this belt, and extending to the West Coast, rural population is sparse, less than 2 persons to the square mile, except in irrigated districts and mining centers. In the extreme West, along the Coast, there are three distinct areas where rural population is relatively dense. From north to south, these are: (1) the Puget Sound-Willamette region; (2) the Great Valley of California and adjacent areas; and (3) the irrigated basins of Southern California. (Courtesy of J. W. Alexander, G. A. Zahorchak, and the *Geographical Review*, Population Density Maps of the United States: Techniques and Patterns, New York, 1943.)

lation distribution which are puzzling. It is difficult to explain, for example, the relatively sparse population of Burma, 60 persons to the square mile, when neighboring areas are so badly congested. Similarly, all the factors operative to produce great local concentrations of population, as in Java, are not known definitely.

Population Distribution in the United States. The same variation in population density which is so apparent for the world as a whole is similarly marked in the United States. For example, though the average density was 44.2 persons to the square mile in 1940, Nevada then supported only one person for each square mile of its land surface. By contrast, crowded Rhode Island, the smallest state in the Union, had 674.2 inhabitants to the square mile in the same year. Comparable variations will be discovered by a study of the three maps: Figs. 6, 7, and 8, which show the distribution of total, rural, and farm population for the United States in 1940.

The present pattern of population distribution

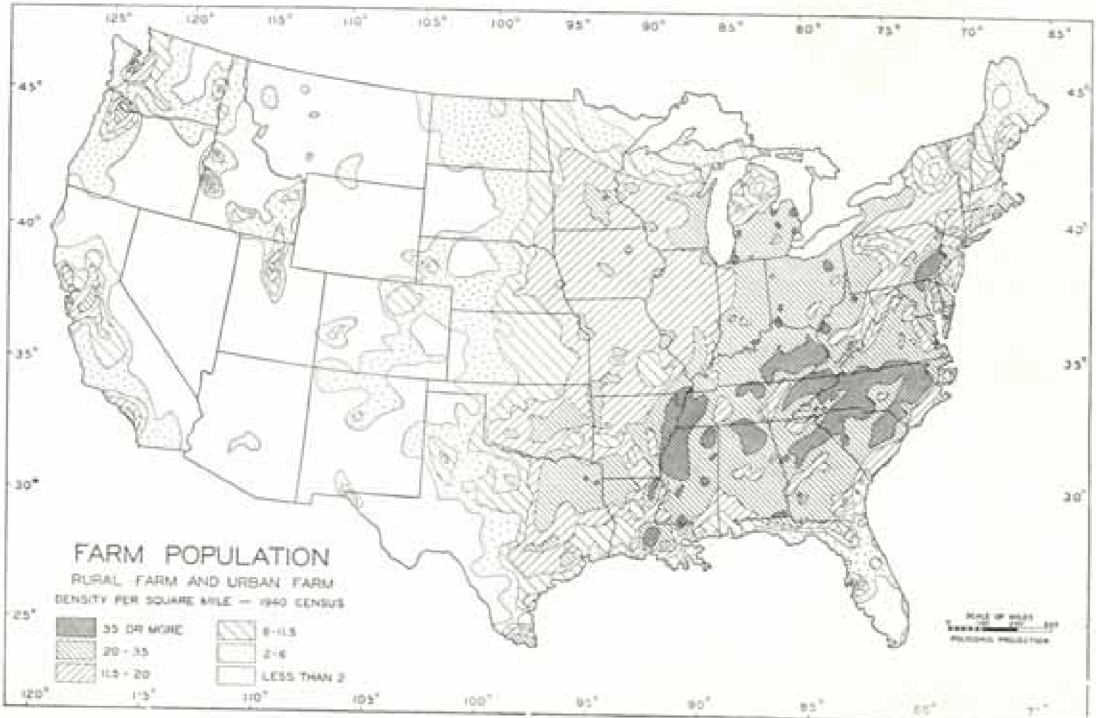

FIG. 8. Distribution of the farm population of the United States in 1940. Farm population is that part of the population living on farms, irrespective of occupation. A "farm" is a tract of land of at least 3 acres, or one with an annual production of $250.00 or more in value.

Though the map showing distribution of total population, Fig. 6, shows the eastern half of the United States to be more densely settled in its northern portion, it is apparent from the map above, Fig. 8, that the southeastern states have a denser farm population. An exception to this general rule will be noted in southeastern Pennsylvania, a very productive agricultural region since Colonial times. This limited area has densities comparable to those of southeastern United States. It will likewise be noted that, with farm as with rural population, densities in general decrease westward in the eastern half of the United States.

In southeastern United States, these moderately high densities of farm population occur not only in the Cotton Belt, but in such poor agricultural areas as the hill country of Kentucky and Tennessee as well. These considerable densities result from a combination of small farms, made possible by cash crops such as cotton and tobacco; a subsistence or semisubsistence type of agriculture in some areas; large families; and generally low standards of living.

In the western half of the United States, farm populations are in general sparse, less than 2 persons to the square mile over extensive areas. Exceptions to this general rule represent irrigated oases, or greater natural opportunity in Pacific Coast valleys, either with or without irrigation, dependent on the adequacy of precipitation. (Courtesy of J. W. Alexander, G. A. Zahorchak, and the *Geographical Review*, Population Density Maps of the United States: Techniques and Patterns, New York, 1943.)

in the United States represents an evolution from that of the Colonial period, when white inhabitants were few in number and settlement was confined largely to the Atlantic seaboard. Shortly after the American Revolution, a slow movement to the west of the Appalachians occurred. At first, the numbers involved were small because of the difficulty and danger of the journey. By the middle of the nineteenth century, this movement accelerated, and, toward its close and at the beginning of the present century, a flood of European immigrants arrived to people the remaining vacant lands to the west of the mountains bordering the Eastern seaboard. This settlement of the interior and of the West Coast has been accompanied by a westward shift of the center of population. This shift was marked for several decades, but, during the 10-year period ending in 1940, it was slight. Since that date, though growth of total population has not been phenomenal and probably will cease completely in the relatively near future, internal movement associated with wartime dislocations has affected location of the center of population materially. This will probably influence the national outlook and life appreciably.

The Present Distribution of the World's Population. The present distribution of man, with its anomalies or peculiarities, is only one stage of a continually altering pattern; the present distribution is not that of the past, nor will it be that of the future. The reasons for these past and present differences in distribution are not fully known. Further they are unpredictable for the future, except in part; for, though certain causes are to some extent permanent in their effects, some no longer operate as in the past; others are now beginning to function; and the future will undoubtedly bring still others into play.

The effects of climatic conditions, for example, though variable with *time*, are probably constant in *character*. By contrast, the oceans, formerly impassable *barriers* to the spread of man, now function to connect the lands and *facilitate* movement. Again, the presence of considerable deposits of certain minerals, early of no importance, today affect regional potentialities, both in the areas where such deposits occur and elsewhere. If and when uses are discovered for other "resources," today considered valueless, they, in their turn, will play a comparable role in their effect on man's distribution.

In addition to the variable effect of factors of the natural environment, such as mineral wealth, at different stages of human development, advance in civilization has produced some conditions which favor population increase and others which operate to ensure stationary or even decreasing numbers. At an earlier period, the belief expressed at the close of the eighteenth century by Malthus, an English economist, that population would everywhere eventually overtake the ability of the earth to support its numbers, was shared by many well-informed persons. Today, by contrast, in highly developed, industrialized societies of the Western world, rising standards of living, increasing urbanization, and the accompanying small families, have dissipated this fear. In its stead, there is now the apprehension that the more intelligent and progressive elements of the white races may be submerged by the rising tide of inferior white stocks, or of colored populations, whose increase still continues essentially unchecked.

To make prediction of future populations of given regions still more difficult, governments have encouraged movement into certain territories by subsidy; in other cases, they have set up barriers, by enaction of immigration laws which establish quotas or even prohibit completely the free movement of certain population groups into designated areas. Laws governing emigration may likewise produce comparable results. Therefore, in view of the uncertainty as to both the factors operative, and their probable actual and relative effects, prediction of the future distribution of man with any great degree of accuracy is manifestly impossible.

QUESTIONS AND EXERCISES

1. In what aspects may areas differ, both as regards natural conditions and those resulting from man's activities? Why has such areal differentiation long been of interest to man?
2. What is the "people's hemisphere"? What is its relation to the "land hemisphere"? Why this relationship? What fraction of the world's inhabitants live in the "people's hemisphere"?
3. What is the probable total world population? How does the probable average density of world

population compare with that of the United States? With that of your home state?

4. How does the population of Australia compare in size with that of prewar Tokyo, Japan? How does the population of all South America compare with that of the four main islands of Japan? What was the prewar population of Tokyo? What is the population of South America? Of South America south of the equator? Of the four main islands of Japan?
5. Why are the lands of the Southern Hemisphere so much less densely populated than those north of the equator? What island in the Southern Hemisphere has a very dense population? What is the total population of this island at present? How rapidly is its population increasing? Who owns this island?
6. State two outstanding aspects or facts of the world's population distribution. How do rates of population increase compare with population distribution as regards variability?
7. For how long a period has man been established on the earth? What evidence have we of that fact? In what types of natural settings did man probably have his origin? Why?
8. Why are tropical highlands preferable to the adjacent lowlands for human habitation? From what handicaps do such highlands suffer? Why are highlands far from the equator relatively less desirable as a home for man than those of the tropics?
9. Locate those parts of the earth which are most densely populated today. Which of these have been densely populated for a long period of time, and which have become densely inhabited rather recently?
10. How does the distribution of population shown in Fig. 5 suggest that diffusion of population probably occurred from several rather than one center?
11. What does the present distribution of the world's population reflect, other than the initial desirability which influenced the first occupation?
12. When did censuses of population begin to attain a fair degree of accuracy? Why was there frequent objection to enumerations of population prior to that date? Why are counts of population for limited objectives, such as determining the men of military age, unreliable as a basis for estimating total population? For how large a fraction of the world's total population do we now have reliable census data?
13. What part of the United States is most densely populated? What supports the population in this part of the country? Which one of the states is most densely populated? Most sparsely populated? Where is the center of population of the United States located at present?
14. What is meant by "rural population"? What part of the United States supports the densest rural population? Why is rural population so dense north of the Ohio and east of the Mississippi River? What three areas on the West Coast have relatively dense rural populations? Why?
15. What is meant by "farm population"? In what part of the United States is farm population densest? Why? What makes the dense farm populations of relatively poor agricultural areas in the southeastern states possible?
16. Why is it difficult to predict future populations for definite areas with any great degree of accuracy? Who was Malthus? What did he predict as to the future for world population? What factors have come into play of late to change our views as to probable future populations?

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This book is an inclusive presentation covering most of the problems of population, some far removed from the field of geography. The eight chapters listed, out of a total of twenty-five, are the most closely related to the discussion of population in *The Earth and Man*.

Vidal de la Blache, P., *Principles of Human Geography*, Henry Holt and Company, Inc., New York, 1926. Part I, Chaps. I–VI.

The first six chapters of this geographic classic are devoted to a general survey of inequalities and anomalies of population distribution, growth of population density, and some of the major agglomerations of the present. This discussion is supplemented by certain inferences and conclusions. The student will find it very suggestive reading.

Chapter Three

FACTORS AFFECTING THE POPULATION PATTERN

Variation in Population Density. Previous consideration indicates a very uneven distribution of man over the land surface of the earth. Since regions which are too dry, too wet, or too cold offer only limited economic opportunity, it is easy to understand why they support few inhabitants, except locally. There, water may offer the possibility of profitable irrigation in dry areas; plantation agriculture may bring limited acreages of the hot and humid tropics into productive use; or valuable mineral deposits in any one of these climatically handicapped regions may tempt exploitation and settlement of some density.

Even in regions of considerable and apparently similar natural opportunity, however, population densities and economic activities are often unlike, and both are subject to change in any given area with the passage of time. Though not all the causes for this are known, some are apparently responsible, at least in part, for such differences. Outstanding in this list is the stage of man's development, which affects environmental values and thereby human choice.

The Environment and Its Function. There is, of course, nothing about any environment, even one offering great natural opportunity, which ensures either a dense population or human progress. Thus an area may be potentially able to support large numbers, yet be but sparsely occupied, with the inhabitants only a few steps removed from savagery. This is because the environment only *offers* opportunity. If great, a large number of people can be supported, yet few may choose to live there; again, the possibilities for many profitable economic activities may exist, but the number accepted will be small. In other words, the environment is a *passive,* not an *active* agent; it *permits,* but it does not *compel.* For this reason, there are parts of the earth's surface where natural conditions are apparently satisfactory, yet population is nevertheless sparse, and development is limited. Environment, then, functions by offering great, moderate, or even severely restricted opportunity, thus modifying the range of the effective choice of both the individual and the population group.

The Environment and Man's Economic Activities. The operation of environment as it affects man's economic activities may be illustrated by the following example. The climate, soils, topography, natural drainage, and other physical conditions of the Ohio Valley are in general favorable for agriculture. Because of this fact, settlers flocked to the region late in the eighteenth and early in the nineteenth century, to take advantage of this opportunity for gainful activity. After arrival, they were confronted with the problem of what crops to plant, for they had a considerable list from which to make a selection, in addition to a choice of agricultural practices to be followed in growing them. In their initial, erroneous beliefs concerning the climate, resulting from accounts by many writers, including Jefferson, production of cotton, rice, and indigo was considered to be possible, even north of the Ohio River. In fact, cotton was actually grown, though not successfully, as far north as Vincennes, in southwestern Indiana.

To attract settlers from the East and Europe, land companies fostered this belief about the climate by advertising the unusual possibilities it afforded for agriculture. For many years, therefore, attempts were made to grow crops which the environment did not permit to be produced to advantage. Even as late as 1880, for example, cotton was grown in many parts of Kentucky, despite the climatic limitation. Today, however,

it has disappeared except along the Mississippi River, in Fulton County, for experience has demonstrated that elsewhere the frost-free season is too short for its economic production.

After elimination of cotton and similarly unsuitable crops, a relatively short list from which to make an effective selection remained: corn, wheat, oats, barley, rye, hay, potatoes, and several others, any one of which could be grown more or less profitably. It will be noted that the environment limited the range of the effective choice of crops, but that it did not determine the specific crops grown. The individual farmer decided: first, that he wished to engage in agriculture; and, second, exactly what crops he would grow, by exercise of his own choice. It is apparent that, in the final analysis, the exact occupations followed in any given area are determined by human choice, either free or restricted, within definite limits imposed by environment. Therefore the environment is a *limiting* factor only. It is equally apparent that neither form of government nor any other factor can offset completely the handicaps imposed by a poor natural environment. Man cannot "conquer nature" by legislation or otherwise; he succeeds only insofar as he adjusts his activities to profit from such opportunity as nature affords.

The Environment and Population Distribution. Where man lives, as well as how he makes his living, is in large part a result of exercise of choice on his part. This is because he is able to move from place to place, except as physical barriers interpose, or the more formidable obstacles of governmental restrictions interfere. Therefore emigration is common, many persons leaving their homelands to seek their fortunes in distant areas. Such a movement was responsible for the phenomenal growth of population which occurred in the United States during the long period of unrestricted immigration, when many individuals and families left western, southern and eastern Europe to come to the United States. These movements of both individuals and groups are motivated by what is conceived to be either a temporary or permanent improvement of opportunity, to be secured by a change of location. Such movements produce many minor alterations in population distribution, and occasionally major changes as well, together with important modifications of economic activities.

Accompanying such movements, except those of minor or temporary character, either absorption or displacement of earlier occupants of the areas invaded normally occurs. This has happened many times in the past, and it likewise often follows today whenever advanced populations take over a comparatively undeveloped area at the expense of primitive native peoples. In our own country, for example, we have dispossessed the North American Indian of practically all his formerly extensive landholdings within comparatively recent years. It is apparent that man's choice as to where he lives operates subject to certain limitations, one of which is his ability to hold possession of, or to secure, by force if necessary, the area desired.

Government and Its Effects on Population Distribution and Economic Activities. The efficiency and form of government affect both population density and kind and degree of economic development. Instability of government makes for general uncertainty as to personal security and the undisturbed possession of legitimately acquired property. It likewise tends to prevent immigration and restrict development. Laws limiting emigration or immigration interfere with the free movement of population. Totalitarian governments interfere with both freedom of choice of where to live and occupation. However, though growth of population and progress may be encouraged, retarded, or even prevented by unwise or punitive legislation, prosperity cannot be attained by government alone.

Therefore, when different parts of the United States, or even of individual states, are compared, differences in degree of progress are found which are considerable, though perhaps not so great as those for the world as a whole. For example, in some of the more isolated regions of the southern Appalachians, our "contemporary ancestors," people whose ways of living have altered very little since the days of the American Revolution, still lead an essentially pioneer type of existence. Though they are of the same population stock, and have been subject to the same laws as have all people in the United States, they have obviously not profited greatly from the government which may have contributed in some degree to the progress and prosperity of others living not far away. It is apparent that legislation alone will produce neither prosperity nor progress. The most it can accomplish is to stimulate enterprise; the worst, to stifle initiative.

FIG. 9. A Kentucky Mountain home on Messer Branch, a tributary of the North Fork of the Kentucky River, near Hazard, Perry County, Kentucky. During the pioneer period and with pioneer standards of living, when population was sparse and game was abundant, this locality was considered favored by nature, for it afforded food, water, fuel, and building material. Under the changed conditions of today, however, with major dependence on agriculture for support, this is no longer true. The only land possible of cultivation is the flat area in the foreground, in corn; the fields in the background, in the process of capture by brush, have suffered so severely from erosion that practically no soil remains. All farm buildings are shown. The house is of log construction, with roof of hand-split shingles and chimney of sandstone slabs, laid with mud for morter. To the left, on the edge of the tree-covered slope, is the family burying ground with its markers. These works of man furnish visible evidence that, though earlier considered desirable by the pioneer, this is today an area where standards of living are low, and in need of rehabilitation.

Limitation of Human Choice and the Results of Unwise Choice. Man's choice operates within limits imposed by environment and government. If these do not restrict too greatly, and choice is wise, the success of the individual will vary in proportion to possibilities fixed by his inheritance; if it is unfortunate, he may even fail, despite his abilities. The fact that certain individuals or population groups live in areas of their own selection, and follow methods of obtaining a livelihood of their own choice, does not prove that the areas chosen were the best available, nor that they are being used to maximum advantage.

Thus it is probable that some people in your own state are living in poor areas, or where only a bare existence is secured by following an unwise method of obtaining a living. These are the so-called "backward" parts of the state, or areas in need of rehabilitation, which frequently means no more than effective use of existing but neglected opportunity.

Environmental Change and Man. Neither the physical nor the cultural environment ever attains a condition of stability. During the more remote geological past, earthquakes, volcanic eruptions, floods, and other phenomena of comparable rank and catastrophic characteristics, plus the processes of weathering, the competition of life forms, and other agencies which operate more slowly and less spectacularly, worked either intermittently or continuously to alter the physiognomy of the earth's surface. With the advent of man on

the scene, changes resulting from the operation of the agencies over which he has little or no control, such as floods, continued, often at an accelerated rate. In addition, others were produced by his attempts to use the opportunities afforded by the natural environment as a basis for support. Some of these changes were slow; others were rapid, as are those caused by the agencies over which he has slight, if any, control. However, their aggregate effect in modifying the environment, and in either increasing or decreasing opportunity for man has, over the period of history, commonly been much greater than that produced by those agencies which have operated both before and subsequent to his appearance on the scene.

During the earlier period of man's existence, his numbers must have been few, the areas he occupied small, and his efforts to obtain a livelihood confined to a few activities, so that the total of their effect on the natural environment must have been limited. This condition persisted for thousands of years, or during that time when man was but barely distinguishable from the lower animals, when his capabilities for causing extensive change were restricted by lack of facilities for their production. As he advanced beyond this extremely primitive stage, however, his ability to effect change of importance increased rapidly; and, the more advance he made, the greater the change he produced. With the passage of time, therefore, both advance, and change made possible by such advance, proceeded at a continually accelerated rate, until today man himself is, through his varied activities, the most important single agent in causing modification of his environment, thereby imposing new limitations on the range of his effective choice.

Stage of Development and Environmental Values. Areal differentiation often results from differences in stage of development of population groups. Thus regions of apparently essential similarity of natural opportunity may be markedly unlike in both population density and the character of their economic activities, if inhabited by populations of different stages of development. The conditions in any given area may likewise change with the passage of time, presenting contrasts similar to those observable between different regions at a given time, as populations of different stages of development preempt the area, or as development occurs within its borders.

This results from the fact that both actual and relative values of the various environmental factors of any given region depend in large part on the stage of development or the culture of its inhabitants. To primitive peoples, for example, a metallic mineral such as gold is of slight worth, except as its color and luster may intrigue their interest. Therefore its attraction to the more advanced white races is frequently incomprehensible to populations of a low stage of development.

Even after considerable advance in civilization had occurred, many resources at present of great importance in both our daily life and industry were considered valueless. This was true of anthracite, or hard coal, known as "stone coal" because of its hardness and appearance. Though combustible, it could not be burned alone in the heating appliances then in use. Therefore it was of interest only as a curiosity, not as a fuel, and was thought to have no economic importance.

Another outstanding example of change in the relative importance of a mineral is afforded by petroleum. When first pumped from shallow wells, it was of use chiefly as a source of kerosene. Gasoline and other lighter distillates were then of much less value, since the market for them was limited. Only after invention of the internal combustion engine, and the large-scale production of automobiles, did gasoline find a ready sale in large volume. Today, however, though of such slight economic significance at an earlier stage of man's development, it plays an almost indispensable part in our daily life and a more and more significant role in world affairs. Peacetime pursuits use it; wars cannot be waged effectively without it; it is so important that it is sought assiduously in many parts of the world by all the great powers. Yet, less than half a century ago, it was considered to be of slight economic value. This illustration of alteration in the importance of a single asset of the environment could be multiplied many times, and the future holds similar, though unknown changes in store. Such changes in the actual and relative values of environmental factors alter regional opportunity and contribute to the evolution of new patterns of areal differentiation, both from place to place at a given time, and within a given area from time to time.

Changing Views of Environmental Values. The history of the past affords many examples of difference in man's evaluation of a given en-

vironment. If, for example, an intelligent Roman citizen of the period when Rome dominated Mediterranean areas had been asked what he thought of the possibility of development of an important civilization in Great Britain, Germany, or the Scandinavian countries, he undoubtedly would have stated that it would be almost inconceivable, for their dense forests, great swamps, and rigorous climates made it an improbability. Today, such a reply seems almost absurd, yet, at that date, the opinion was intelligent and intelligible; for, at the then-existing stage of man's advancement, he could not cope effectively with the environmental conditions of those northern regions. Thus it appeared that they were doomed to a permanently low stage of development, and to occupancy for all time by "barbarian" populations. The Roman citizen thought of such areas much as most people think of the polar regions today, as ones of permanently low possibilities and development.

Much later, but still long ago, during the earlier period of colonial occupation of the North American continent, various objectives motivated exploration and settlement. Today, however, few of the opportunities then thought to be afforded by environment bulk large in determining man's choice of economic activities in the areas which attracted early Spanish, French, and English attention. To the Spaniards, the New World was a land of almost fabulous wealth; the major attractions were the supposed stores of gold, silver, and precious stones; and the presence of such miraculous resources as a fountain, the waters of which would restore youth. These supplied the incentives which led Cortez to invade Mexico, Pizarro to overrun the empire of the Incas, and De Soto and Ponce de Leon to explore the southeastern United States. The French likewise penetrated and occupied the Canadian interior to carry on activities different from those which today supply the bulk of the income of our neighbor to the north. Thus their interest, aside from that prompted by missionary zeal, was mostly in the fur trade, not agricultural possibilities, forest, and mineral wealth, all of the latter now much more important in the economic life of the Dominion. Similarly, English occupation of the Atlantic seaboard of the United States was based on conceived agricultural opportunity which has for many years been known to be practically nonexistent in most of the areas of early settlement. Therefore industrial development has almost completely supplanted agriculture in many of them, as a result of our changed view of, and actual change in, environmental opportunity. Even where industry has not appeared, many of the early farms have reverted to forest; for experience has demonstrated the futility of attempting most types of agricultural production on the poor, sandy soils of much of the southeastern seaboard occupied by early English colonists.

Change of views with respect to the relative environmental values of different areas continued, not only during the Colonial period, but for many years thereafter, down to the present day. For example, in 1867, at the time of the purchase of Alaska, long known as "Seward's Folly," many intelligent individuals thought the expenditure involved unwise. Time, however, has proved the purchase economically sound, and an outstanding example of a profitable investment, either private or public; for the purchase price of $7,200,000 has already been returned nearly three hundredfold. Further, strategic considerations alone would today justify acquisition of this territory: an outpost on the great circle, or shortest route to eastern Asia.

These changing views with respect to both actual and relative desirability of the environments of given areas are sometimes related in part to actual changes in environment, but at least as often to the stage of man's advancement. To illustrate this fact, the limiting effects of environment on populations of different stages of development will be considered briefly.

Environment and Primitive Man. Primitive man is much more limited by the local environment than is civilized man. This is because he must obtain everything he needs from the area where he lives, or its immediate vicinity. Therefore he must construct his shelter from whatever is available near by, fashioning it from dried mud, or sun-dried brick, if no more satisfactory material is close at hand. In similar manner, he must make his clothing from plant fibers or animal skins obtainable in the home area; and his food supply is abundant and varied in kind, or scanty and lacking in variety, depending on local resources. Even his tools and utensils must be devised from whatever the immediate locality affords. Everywhere, therefore, the environment of the home area imposes serious restrictions on

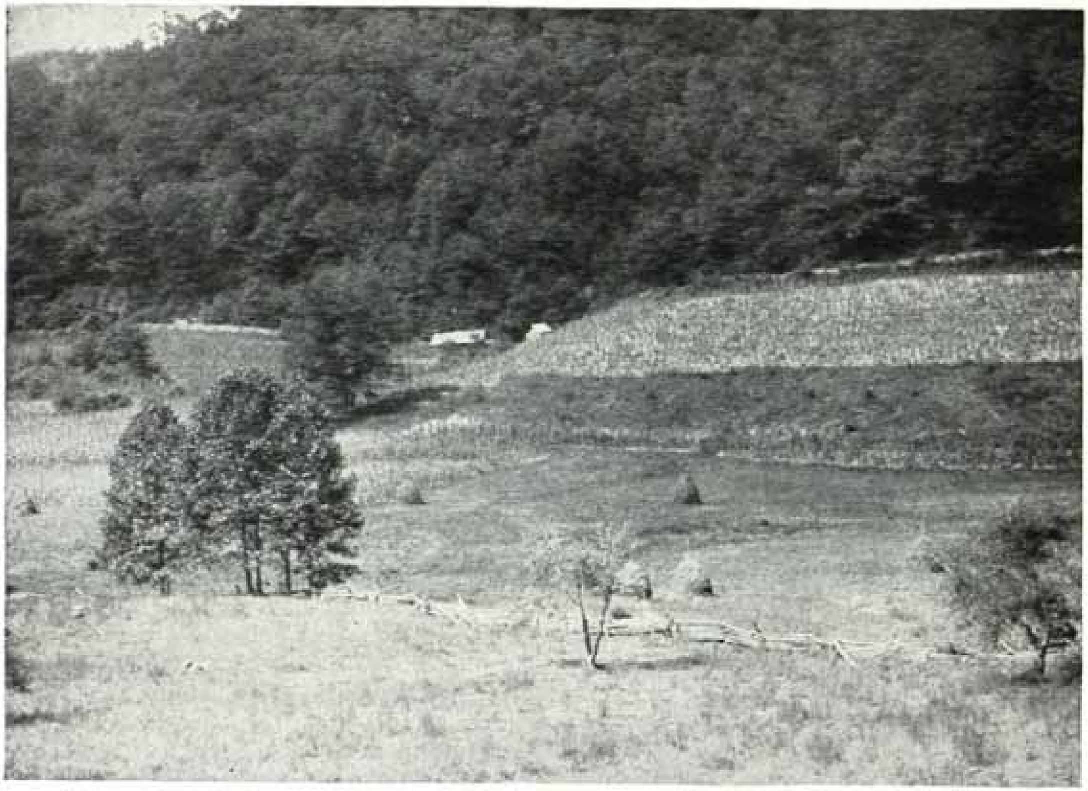

FIG. 10. An area of great natural beauty and an excellent setting for pioneer occupation in the Valley of Greasy Creek, Harlan County, eastern Kentucky. Flanking the valley on either side, the steep, forested slopes of Black and Pine mountains supplied fuel, building material, and, for many years, game. The level land along the creek afforded pasture and the opportunity to grow corn. Springs and the creek furnished water for domestic use and for livestock. From the point of view of the pioneer of an earlier period, this was an area of opportunity and promise.

savage populations, which practice complete or essential self-sufficiency; that is, depend entirely, or for the most part, on their own exertions, and the resources of the home region or near-by areas to satisfy their needs. Among such populations, the relative desirability of areas is of necessity determined almost entirely by the degree of self-sufficiency made possible by the natural environment.

The Early American Pioneer and Environmental Values. Among the earlier pioneers, as with primitive populations, though in lesser degree, the practice of self-sufficiency was general. In the earlier history of the United States, for example, the settlers west of the Appalachians were cut off from contact with the Atlantic seaboard by forested topographic barriers, without highways other than poor trails. Thus only a few articles, small in bulk and high in value per unit of weight, could be brought in from the outside, even had the pioneers possessed the means to purchase them, which was generally not the case. Therefore essential self-sufficiency was the rule. Food was obtained locally by limited tillage of the soil, and by hunting and fishing; surplus corn was converted into whiskey. Houses and other buildings were of log construction. The forest likewise afforded fuel, support for domestic animals such as swine, and the material for making crude furniture. Clothing was made from the skins of animals, and from yarn spun and woven into cloth by the pioneer women. Light was furnished by hand-dipped candles or flares, and most of the minor wants were similarly satisfied from local resources.

During this period, the pioneer judged the relative desirability of areas on the basis of whether they permitted attainment of essential

self-sufficiency. A forested region was preferred to one without trees; one abounding in game to one that did not offer such a source of food supply; one with springs and surface streams to one lacking those assets. If a limited amount of cultivable land with fairly productive soils was available, it sufficed for the pioneer crop, corn. Only with increasing population did topographic limitation of productive area become important The earlier pioneer settlement, therefore, was in forested regions bordering stream courses; the flat and fertile prairie grasslands of the interstream areas were not occupied until much later, when changed views as to their relative desirability prevailed.

Present-day Views of Envrionmental Desirability. With man's increasing advancement, and particularly with improvement of means of transportation, criteria for judging relative areal desirability have altered. Though it is still true that a region presenting diverse possibilities is more desirable than one where opportunity is limited to a smaller number of choices of possible profitable economic activities, the latter may today be of much greater importance than it was during earlier periods of history. This is largely because of the possibilities for exchange inaugurated by our modern system of transportation.

This present ability to exchange the products of one area for those of another has led to specialization of effort and production where most effective, except as the desire to attain national self-sufficiency may interfere. It has likewise enabled the accumulation of skills in specialized production, and material additions to the world's supply of goods, both in kind and quantity. Scarcity, a condition inseparable from primitive and early pioneer methods of obtaining a livelihood, make for little to distribute; abundance, resulting from man's effective production in the most favored areas, has resulted in a greater supply of material possessions and has been conducive to steadily rising standards of living. This change has contributed to accentuation of areal differentiation, in addition to an alteration of the pattern. It has likewise led to certain evaluations and results which will be considered briefly in the following pages of this chapter.

The Poleward March of Civilized Man. One of the important results of changing views as to the value of given environments is the increasing importance of the higher latitudes and the poleward march of population and civilization. For long confined to areas of moderate to high temperatures, man has at last attained a stage of development in which long, severely cold winters have lost much of their former terror. Today, settlement, some involving limited agriculture, made possible by development of crops which will mature during a short frost-free season, has pushed far to the north, within a few miles of the Arctic Circle. Some enthusiasts claim that the end of this poleward extension of the settlements of civilized man has not been reached as yet.

FIG. 11. Wheat harvest time near North Battleford, western Saskatchewan, Canada. Here, the grassland passed into use without the necessity for clearing and the flatness of the country made effective mechanization of agriculture a possibility, leading to low costs of production on the generally large farms of the region. It is agricultural invasion of such areas that has led to great increase in the world's food supply, and thus contributed materially to raising the standards of living. (Courtesy of the Canadian National Railways.)

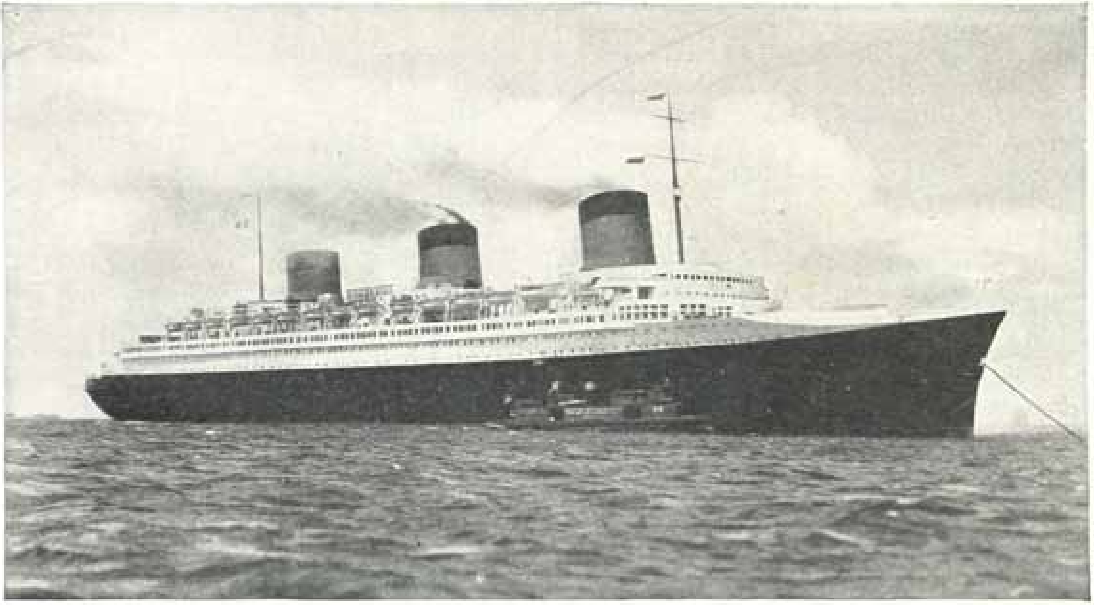

FIG. 12. A modern ocean liner. This vessel, 1029 feet in length and 119 feet in width, carries an enormous amount of freight, in addition to having accommodations for 1960 passengers. Passengers and crew together, the crew numbering 1300, equal the population of New Bedford, Massachusetts in 1790, at which date that town was the eighth largest urban center in the United States. It is the evolution of such improved means of travel and transportation which make return to the isolation and self-sufficiency of the past impossible in practice. (Courtesy of the French Lines.)

Certainly it is true that we have of late become increasingly interested in the wastes of snow and ice of the Arctic and Antarctic, and the staking out of claims in these polar deserts. Some of this interest in high latitude possessions attaches to their probable future importance as locations for air bases; some is the result of scientific interest in a study of their meteorological conditions as a means to a more satisfactory understanding of the weather of intermediate latitudes; but, in some degree, the interest arises from the possibility of discovery of resources, particularly minerals, which may serve as the basis for support of populations in those days when development of transportation will permit occupation, probably in the near future.

Interdependence and Trade. With their present specialization of effort and numerous wants, civilized populations are dependent on many and often distant regions for a considerable part of their food, clothing, and other requirements. To satisfy these wants, it is necessary to exchange goods between areas. But such trade necessitates contacts, making life much more complex than among savage and semisavage peoples, who have few if any commercial dealings with their neighbors, either near or remote.

This interdependence of populations is recent, for less than two centuries ago people satisfied most or all of their needs from the home region, though at present this is the exception rather than the rule. Even on the frontiers of human occupancy, the inhabitants may, and often do, obtain many manufactured articles such as clothing and utensils from the industrialized areas of highly developed regions. Today, commerce has broken down the barriers which existed in the past, and, for most parts of the world, complete economic self-sufficiency is almost impossible in practice, as well as undesirable.

Interdependence and Transportation. This great change has accompanied improved methods of communication and transportation. Within less than a human lifetime, we have come to accept the products of distant areas as a matter of course. Communication by spoken word between our Atlantic and Pacific coasts, impossible a century ago except after a time-consuming, difficult, and dangerous journey, is at present a matter of minutes only. The trip from Chicago to

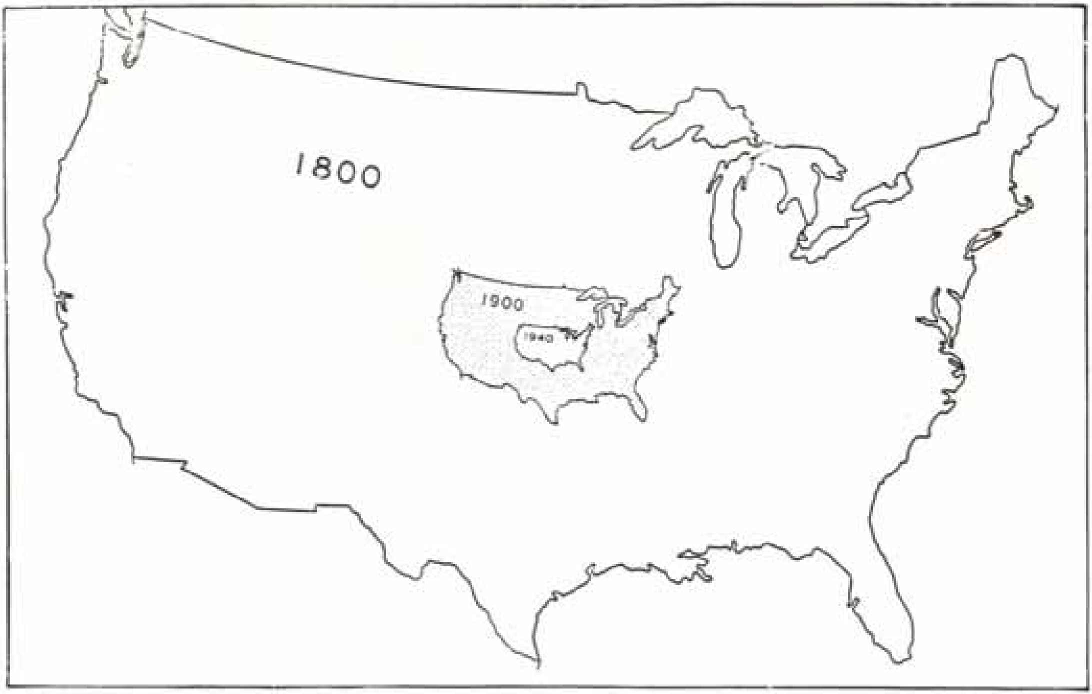

FIG. 13. The shrinking United States. In 1800, rapid travel was at a rate of not to exceed 10 miles an hour; by 1900, it had risen to 35 miles by sea and 60 miles by land; by 1940, to 180 miles or more by air. Today, the maximum promises to be fixed only by man's physical limitations. The variable size of the United States, measured by accessibility based on the rates of travel for 1940 and earlier, is shown above.

New York, formerly requiring days, can now be made in about 3½ hours; even by use of regularly scheduled flights, it is possible to breakfast in San Francisco and dine in New York on the same day. Thus improved methods of transportation have annihilated distances, and each year this becomes increasingly true. Any attempt to return to past conditions of isolation and self-sufficiency would work enormous and detrimental changes in our existing civilization, as well as be virtually impossible in practice.

Commerce and Friction. With contacts and accompanying commercial and political relations between countries and populations established, opportunities for misunderstandings arise, and, from the friction which develops, even war may result. The present offers many illustrations of the fact that this is a possibility.

To solve the problems arising in connection with trade between different areas intelligently, it is desirable to know something about other parts of the world, and the conditions under which their peoples live and work. We need many things which other countries can produce more effectively, and we, in turn, can often supply their inhabitants with what they need but cannot secure to advantage locally. Obviously, if we know the problems of the areas with which we trade, we are in a much better position to reconcile apparently conflicting interests and arrange our trade relations more intelligently. Therefore a knowledge of other countries and of the problems which confront their populations is fundamental for living successfully in the present-day world, with its complex industrial and commercial development, made possible by interdependence.

Stage of Development and Areal Differentiation. The great contrasts between the life of essentially self-sufficient peoples and that led by interdependent populations result from differences in culture or stage of development. This thereby becomes a factor in causing areal differentiation, manifesting itself in population density, distribution, and activities. In the same manner in which areas may differ from one another at

any given date because of the various stages of development of their populations, any given area will change with the passage of time, if the culture of the population alters.

Environmental Change and Regional Planning. In view of the continually altering values of the various environmental factors, both actual and relative, with the passage of time, all planning for effective use of a definite area at a given time must apply to that date only. In fact, some of the present difficulties of certain areas arise from perpetuation of use based on past conditions, despite change.

From this, it follows that realistic planning for the effective use of any area is a continuous process. Future possibilities as well as present conditions should be considered; and plans for present utilization should have sufficient flexibility to permit of modification without substantial loss, for only in this manner can man take advantage of continually changing opportunity in an effective manner. Further, any planning for use of an area should be based upon as nearly a complete inventory or list of regional assets and possibilities as it is practicable to assemble. Otherwise, neglect of some essential but unknown factors may invalidate the recommendations, which obviously must be subject to a considerable possibility of error, if based on incomplete information.

QUESTIONS AND EXERCISES

1. How does human choice function to affect population density and distribution? What shifts of population have occurred as a result of the war? Why?
2. Name some "backward" area, in your own state if possible. Is it densely populated? How do the people who live in this area make their living? Are they prosperous? Does the state contribute to their aid in any way and, if so, in what manner?
3. How does environment affect human activities? What is meant by the statement that the environment is a "passive agent"? Does a favorable environment always ensure progress? If not, why not?
4. Illustrate how man comes to follow a given occupation by some example of the effect of environment on human choice. If possible, select the example from your home state.
5. Why is it impossible for the environment of any area to attain permanent stability? Why was man relatively ineffective in producing environmental change during the first few thousand years of his existence on the earth?
6. Illustrate the changes in relative importance of the environmental factors at different periods in the history of your home state.
7. Name some minerals, in addition to petroleum and hard coal, that have become of greatly increased importance during the past 50 years. For what are they used? What mineral, mined in northern Canada, has attracted much attention of late? For what is it used?
8. Explain why savage man is more limited by his immediate environment than is civilized man. Why do savage populations have to depend almost entirely on the home area for everything they need and use?
9. Why did the Romans consider northwestern Europe an area of relatively low desirability? What incentive induced Pizarro to invade the empire of the Incas? Why was the Alaska Purchase considered unwise by many intelligent and well-informed persons at the time it was made? In what respects has the purchase been very fortunate?
10. What type of area attracted pioneer settlement in the United States after the American Revolution? Why have many such areas declined in attraction with the passage of time?
11. In what type of area did agriculture have its beginnings in the United States? How has the spread of agriculture into the grasslands affected the world's food supply? How does specialization of agricultural and other production affect costs? Why?
12. How has man been enabled to push into higher and higher latitudes effectively? What is our present interest in polar areas? What may be the future importance of such regions?
13. Why may an area that is not good for savage occupancy afford opoprtunity to civilized man? How and in what ways would a return to economic self-sufficiency affect your everyday life? Has human progress made your home area a better place to live and, if so, in what respects?
14. Why is definite planning for use of an area preferable to the trial-and-error method common in the past? In what respects does continuous environmental change and change in environmental values have to be taken into account in planning for the most effective use of an area?

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This chapter discusses the potency of environment; its effects on plants, animals, and man; the formation of complex ethnic groups; races; and modes of living. The presentation is simple, clear, and interesting.

Weigert, Hans W., and Stefansson, Vilhjalmur, editors, *Compass of the World*, The Macmillan Company, New York, 1944, Chap. IV, pp. 215–265, 312, 335.

These two parts of Chap. IV, the first by Vilhjalmur Stefansson, the second by Graham B. Grosvenor, supply a modern and advanced view of the North American Arctic, and the role aviation will play in the probable future of polar areas. The reader should find them both interesting and provocative of thought.

Chapter Four

ECONOMIC ACTIVITIES AND THE POPULATION PATTERN

Stage of Development and Population Distribution. The culture of the inhabitants of an area affects both the number of people a region supports and their distribution within its borders. Therefore populations attain maximum density only where the stage of development is such that certain types of productive human activity serve as the basis for man's support. Elsewhere, they vary greatly in concentration, though always bearing a definite relationship to the means of obtaining a livelihood. That this is true will be evident after comparing the two generalized maps, Figs. 5 and 14.

Similarly, though not shown by the maps, distribution of population *within* areas having the same economic activities follows a common pattern, with minor variations only. Such correspondences between the distribution of man and that of his economic activities are so marked and persistent that it would be highly improbable they were the result of mere coincidence.

Therefore it is desirable to note these relationships, with a view to formulating some generalizations concerning man's numbers and distribution over the earth's surface. With these in mind, the intricate pattern of the population map loses some of its apparent complexity and seeming lack of plan; a better understanding of the past and present distribution of the world's inhabitants becomes possible; and, perhaps even more important, a more adequate and realistic appraisal of probable future population densities can be made.

Primitive Man and Population Distribution. The world's population must have been small during prehistoric times, when only primitive peoples inhabited the earth. This is because Nature, unmodified by human activities, does not permit support of large numbers. In those earlier times, then, even though man did not purposefully limit his natural increase—which he undoubtedly did if only by allowing the physically unfit young and the old to die prematurely—dense populations were impossible.

This condition must have persisted for many centuries, during which man's numbers remained essentially stationary. Up to within the past one hundred years, indeed, there were many parts of the earth's surface where a similar restriction on population increase continued operative. Even today, there are certain climatically handicapped regions where the number of inhabitants remains practically unchanged with the passing years.

Progress and Population Distribution. After many centuries, however, man's stage of development in the more favored parts of the world became such that he was able to wrest a living from a relatively unfriendly earth more effectively. Then his numbers began to increase. This was true not only in those places where he made his first apearance, but in others as well, which up to that time had limited opportunity so greatly that they remained either essentially or totally unoccupied. Thus population increased in the areas of initial opportunity and man spread into surrounding regions. There, he likewise increased opportunity by his activities, and thereby also the possibility for support of additional numbers. It will be noted that both the increase in numbers and spread of population were a result of change in the stage of human development.

Civilized Man and Population Distribution. Few if any *exposed* parts of the earth's solid crust are totally without inhabitants at the present period of human history. Only the frozen wastes of snow and ice of the higher altitudes and latitudes, where the earth's land surface is often deeply buried, may possibly qualify for the dubi-

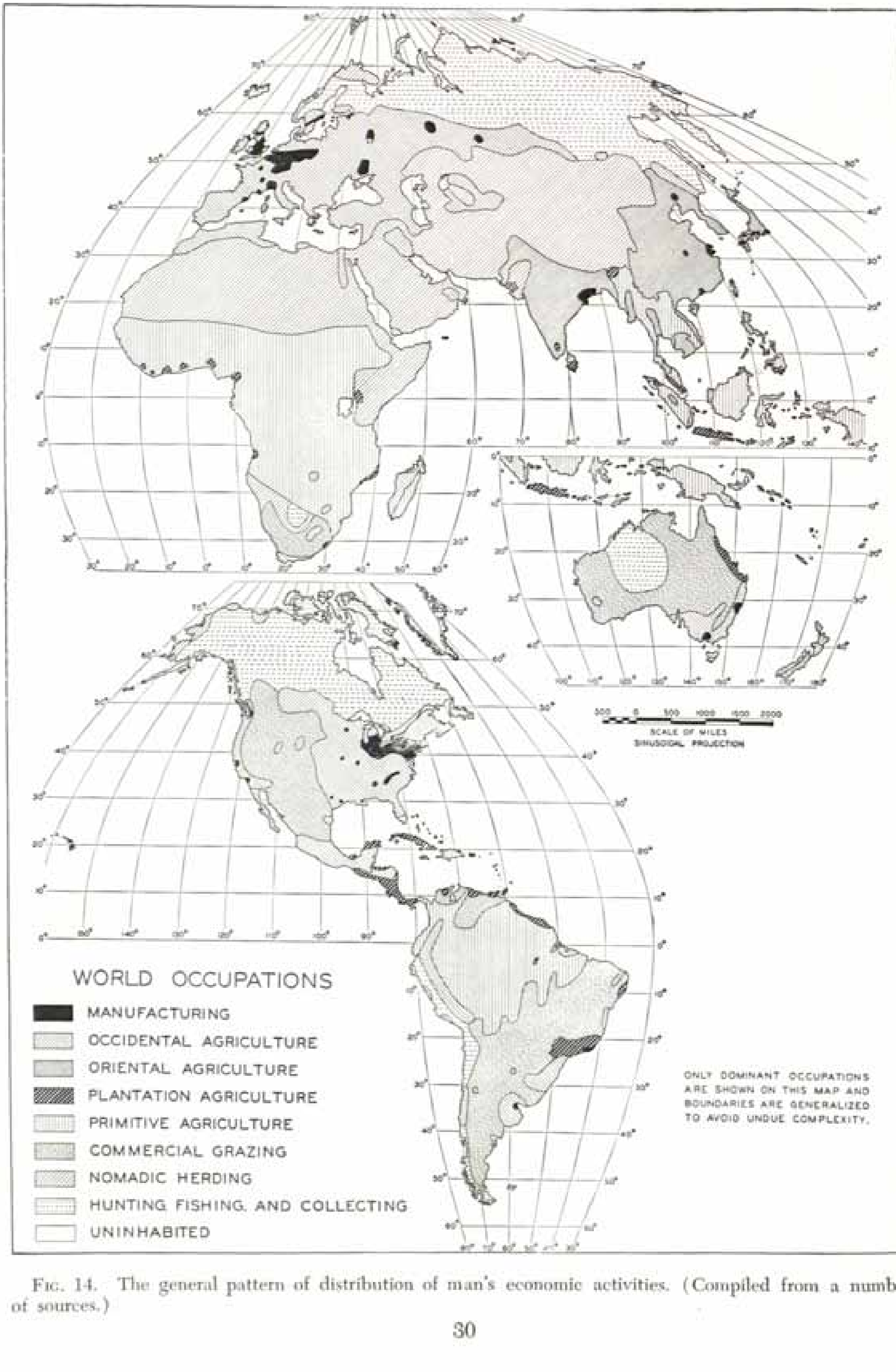

FIG. 14. The general pattern of distribution of man's economic activities. (Compiled from a number of sources.)

FIG. 15. A group of migrating Kalahari Bushmen of Southwest Africa, with all their worldly goods. Frequent shifts of location are necessary where hunting supplies most of the food, as it does for the inhabitants of this dry area. Therefore shelters, which are occupied for only short periods of time, must be of simple construction, and material possessions are limited. (Courtesy of the South African Railways and Harbours.)

ous distinction of so lacking opportunity that man cannot establish himself there. Even for some such areas, however, there are indications that this may not long be true.

These changes in past and prospective populations which have been noted are the result of increased opportunity based on man's present varied possibilities for support, dependent on both natural resources and economic activities either unknown or considered of no importance a comparatively short time ago. In the following pages, it is proposed to discuss some of the more important of the many economic activities of present-day populations, in order to obtain an adequate idea of what each offers in the way of opportunity, and the effect each has on population numbers and the pattern of population distribution.

Migratory Hunting Populations. Migratory hunting populations live in practically all latitudes. The Eskimo, for example, live where winters are both long and cold, and the land is so inhospitable and lacking in opportunity that they must turn to the sea for most of their support. Slightly nearer the equator, where the environment is somewhat more favorable, the Yuraks of the Lower Ob in Siberia, in the Northern Hemisphere; and the Onas of the main island of Tierra del Fuego, in the Southern Hemisphere, also obtain a living by hunting, but on the land, as did our Plains Indians prior to preemption of the larger part of their home areas by whites. In and on the margins of the tropics, the Australian Blacks and the Bushmen of the Kalahari, both dependent on the chase for a livelihood, occupy true deserts. Inhabitants of the rain forests of equatorial regions, such as the Pygmies of central Africa and the primitive Indian tribes of the Amazon Basin, are likewise nomadic hunters. It will be noted that not all of these areas occupied by nomadic hunters are shown on the map, Fig. 14, because of its small scale.

Such an activity as hunting can at best support only a relatively sparse population, and, when the characteristics of the areas in which migratory hunting populations live today are considered, it is not difficult to understand why few people live in them. All have repressive environments: too cold, too dry, or too wet. Thus, in all areas occupied by such populations today, there is seldom more than one person to the square mile, and, because of the frequent shifts of pasturage, the pattern of population distribution lacks permanency.

Migratory Pastoral Populations. Important areas where nomadic herding is the dominant economic activity are at present confined almost entirely to the Old World, particularly to Asia and Africa. In Europe, such areas are of limited extent; in the New World, true pastoral nomadism is probably nonexistent, though the Navajo Indians of southwestern United States lead a seminomadic life.

Though they occur in the warm, the cool, and even the cold parts of the world, most of the semiarid, desert, and other generally treeless regions, where man depends upon flocks and herds and leads a migratory existence, are in intermediate latitudes, or on their margins. The poorness of the pasturage in these areas not only entails a nomadic type of life, or endless wandering, but it also prevents support of large numbers of people. Among the Kirghiz, a pastoral population of central Asia, such migrations may involve hundreds of miles of travel. Those of the Mountain and Forest Lapps, or Samelats, the name by which they prefer to be known, are, on the contrary, not so extended, being restricted to certain relatively small districts, delimited by hereditary rights.

Where environmental conditions limit man to a nomadic existence, the temporary character of the occupation of any given area must result in a continuously shifting pattern of population distribution.

Populations Supported by Commercial Grazing. Commercial grazing, by contrast with nomadic herding, preempts not only poor steppe, desert, and tundra, or the treeless plains of the Arctic, but much of the better steppe, or dry grassland, as well. This economic activity is likewise important in both the Eastern and Western hemispheres, and both north and south of the equator. In this respect, also, it differs from nomadic herding. Again, where nomadic herding is practiced, the flocks and herds range over extensive areas; in commercial grazing, the range is restricted and movement from one pasture to another is for relatively short distances.

Further, the objectives are different in these

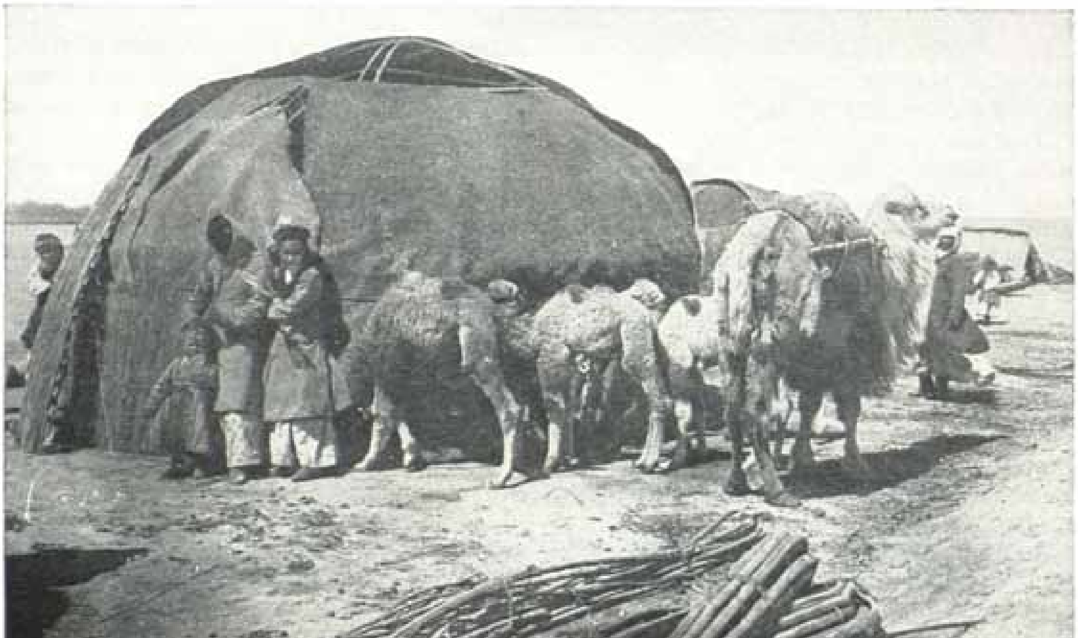

FIG. 16. Kirghiz of the high plateaus and dry steppes or grasslands of central Asia, their tent or "yurt," and their camels. The Kirghiz are a nomadic pastoral population, dependent for support on sheep and goats. That they live in a dry area is indicated by their use of camels as beasts of burden, though they also have others: horses and donkeys. Their food, their clothing, and their equipment are supplied by animals; even their yurt is of felt. (Courtesy of Theodor Benzinger.)

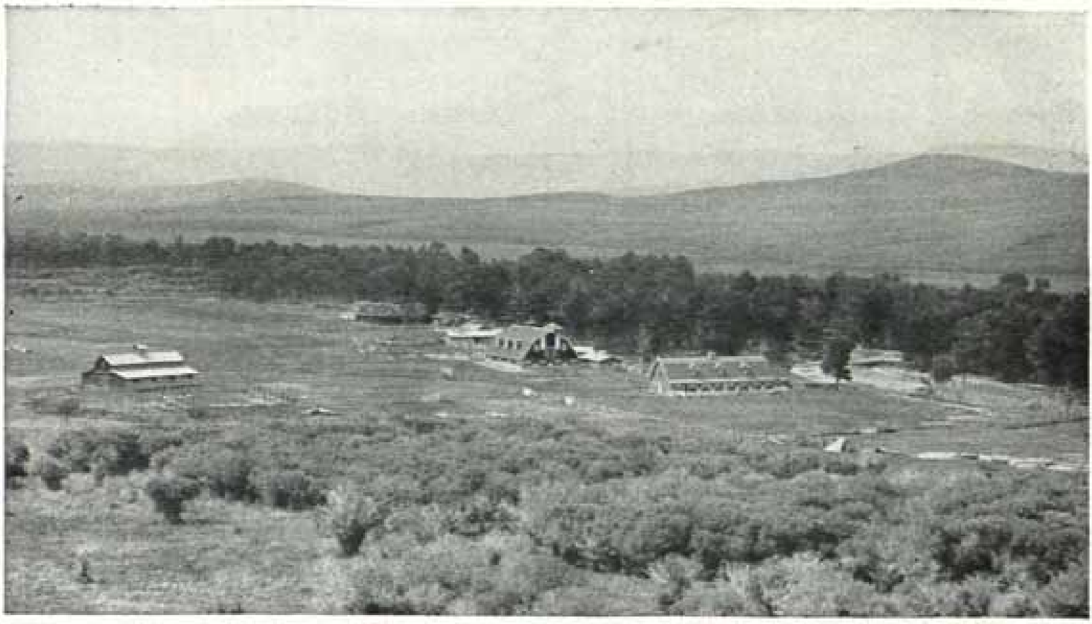

FIG. 17. A Canadian ranch with better-than-average buildings, about 25 miles south of Calgary, Alberta, on a tributary of the Bow River, which affords water for livestock. To the west, the Selkirks are visible in the background. The lower land near the stream, where water supply is adequate, supports tree growth, but the sagebrush in the foreground indicates that this is a rather dry area, annual rainfall being less than 16 inches. Though too dry for effective agricultural use without irrigation, the area is well adapted to grazing, the most important economic activity of the region. (Courtesy of the Canadian Pacific Railway.)

two methods of obtaining support by the grazing of animals. In nomadic herding, the animals supply essentially all the needs of their owners, but there is little or no surplus available for exchange or sale. In commercial grazing, on the contrary, the objective is production of a surplus, which is sold in world markets.

Though this is not everywhere true, in regions of commercial grazing in the United States and Canada, the range may be fenced and the flocks and herds supported on a relatively small tract of land or ranch, feed being supplied when the range does not afford satisfactory pasturage. Even under such conditions, population densities are necessarily low, because much land is needed for the support of each animal. Nevada, for example, with grazing of this type one of the few important economic activities of the state, has a population density of less than two persons to the square mile, the lowest for any state in the United States. In the case of such occupation, however, the population, though scattered, is fixed in location: concentrated where water is available, sparse where it is lacking. This gives a definite pattern of occupancy, related to water supply.

Primitive Tropical Agricultural Populations. Sometimes agricultural practices are very crude, as among the primitive, migratory, negroid tribes of the equatorial forests of the Congo basin. Their villages, composed of rectangular houses with thatched roofs, arranged along a single street, are located near streams, which serve as highways. Behind the houses are groves of plantains, a species of banana, and small gardens which provide against emergencies. At variable distances from the village, but never far away, are the larger clearings which supply most of the food. Agricultural practices are very simple. Underbrush is removed and the larger trees are hacked off several feet above the ground, at the point where their trunks decrease in size. Then the clearing is burned over and plantains, manioc, fruit, and vegetables are planted in the soil enriched by the burning. Such tracts produce satisfactorily for about two or three years, by the end of which time the small amount of available plant nutrients in the soil is exhausted. Then another

FIG. 18. A Congo basin agricultural village, located in a small clearing near a river, which serves as a highway. The thatched houses on either side of the irregular street, which terminates at the river in the background, are of simple construction. Therefore, when the village is abandoned, there is little loss. This area is warm throughout the year, a fact indicated by the house type and the dress of the people in the foreground. (Courtesy of the Keystone View Company.)

clearing is made and planted and the old one is abandoned. This type of agriculture is practicable only in sparsely populated regions where there are large tracts of unused land. Elsewhere in the world, though formerly more widespread, this type of agricultural use of the land has disappeared almost completely. Though population is sparse and shifting in areas where this type of agriculture is practiced, the importance of rivers as the principal highways makes for a more or less fixed distribution of habitation, related to the major elements of the drainage pattern, which offer transportation possibilities.

Oriental Agricultural Populations. In parts of the world where the land has been in productive use for many centuries, as in China and southern Japan, populations are often extraordinarly dense and practices are very different from those of primitive tropical agriculture. In such regions, the peasants, using no machinery, and few and simple tools, grow at least one crop each year on all fields, an entire family deriving its support from two or three acres of land, an area less than an average city block.

This is made possible by very intensive use of the land under cultivation; or by the expenditure of much labor in planting, caring for, and harvesting the crops grown; and by heavy fertiliza-

FIG. 19. In this agricultural area of southern Japan, all of the flat land is under cultivation, producing both a summer and a winter crop, year after year, on the heavily fertilized fields. Farms are small, less than the size of a small city block, and fragmented. The farmhouses are located at the foot of the slopes in the background, which are too steep for agricultural use. Almost all of the work is done by hand. Even the two-wheeled farm carts are drawn and pushed by the peasants on narrow roads satisfactory for use by such vehicles, but not adapted to the needs of modern transportation. In the illustration, the peasants are wearing typical Japanese shoes, which are held in place by a thong between the toes. In such an area, hours of work are long and standards of living are low. (Courtesy of Theodor Benzinger.)

tion with human wastes, in the absence of animal manure and the lack of means to purchase commercial fertilizers in sufficient quantity. It is likewise the common practice to grow two or more crops each year on the same field, wherever this is possible. Further, whenever and wherever possible, the crop grown is rice, of all the cereal or grain crops the one which produces the greatest returns in food value per acre of land under cultivation, if grown under favorable conditions. By thus forcing the land to yield maximum returns by both agricultural practices and selection of crops, the support of large numbers becomes possible.

Not only are populations dense in such areas—sometimes as many as 6880 persons to the square mile in the rice-growing districts of Chekiang and Kiangsu in China, according to Mallory—but they are also sedentary, with a pattern varying with the character of the agricultural area, the number and kinds of crops grown, the means of transportation, and other factors.

Populations Supported by Occidental Types of Agriculture. Agricultural populations of Occi-

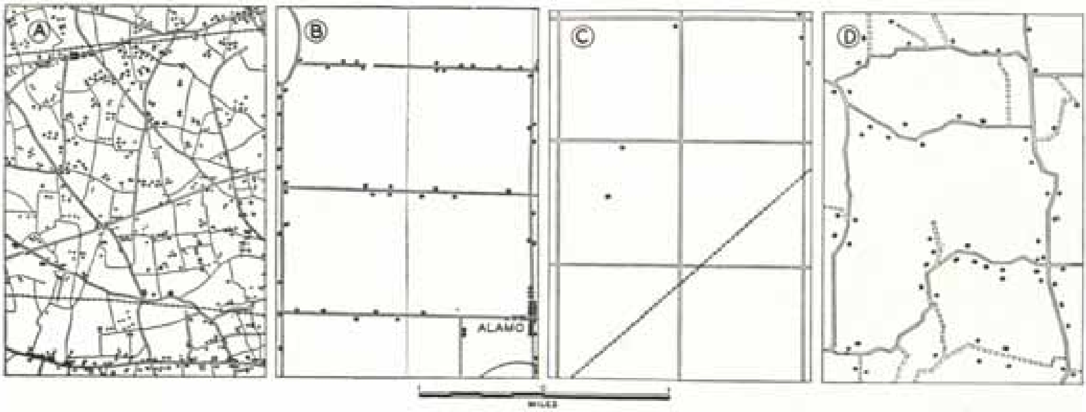

FIG. 20. Contrasts in densities and patterns of Oriental and Occidental agricultural occupancy. All four maps are of equal areas, and drawn to the same scale to make these contrasts evident.

(A) An upland agricultural area on the Kwanto Plain, about 10 miles to the west of Tokyo, Japan. Population densities are everywhere high, well over 500 persons to the square mile, but the distribution pattern varies. In some cases, the peasants live in grouped dwellings or in compact agricultural villages; in others, their houses are arranged in linear fashion along highways.

(B) An agricultural area in northwestern Kalamazoo County, southern Michigan. Density of the rural-farm population, or that part of the population living on farms, is much lower than in Japan, being slightly less than 23 persons to the square mile for the entire county. Farmers do not live in villages, but on their farms, houses being separated, with the pattern of distribution related to the rectangular road mesh.

(C) An agricultural area in Cass County, eastern North Dakota, about 10 miles from Fargo. In this county in the Red River Valley, farms are large, averaging nearly 400 acres in size, as contrasted with less than 100 in Kalamazoo County, and density of the rural-farm population drops to a trifle less than 8 persons to the square mile. The pattern of distribution, as in southern Michigan, is related to that of the roads.

(D) An agricultural area, with a largely white population, in the southeastern United States: a part of north-central Cobb County, central Georgia, about 30 miles northwest of Atlanta. Here, the roads do not form a rectangular mesh, but are adjusted to topography rather than to a system of land survey. Houses are quite closely spaced along these irregular roads, for this is a region of relatively small farms, 30 per cent of which are less than 30 acres in size; the average of all is slightly less than 60 acres. Such small farms, with farm families of some size, produce a density of rural-farm population of nearly 48 persons to the square mile in this area. This is nearly five times the average for the United States.

dental areas vary greatly in density, but seldom attain Oriental averages and never their maxima. In parts of the United States, and in other countries with similar climatic conditions, wheat, barley, and other food crops are sometimes grown on large landholdings, with much use of machinery in production. Normally, however, in those parts of intermediate latitudes inhabited by white populations, crops are raised on relatively small farms, though there may still be an extensive use of laborsaving machinery, with production conditions very different from those of Oriental agriculture, even where the conditions of the physical or natural environment are essentially similar. Ordinarily, therefore, populations are of moderate density and the pattern of population is stable.

The present needs for certain products of tropical agriculture, such as rubber and sugar, are so great that native production alone is insufficient to meet the demand. Because of this, whites have invaded some parts of the tropics and introduced their agricultural practices, in somewhat modified form, into these warm areas. Where this has occurred, the subsistence type of agriculture practiced by native populations has been displaced by large-scale or commercial production of such crops as rubber, sugar, bananas, and others, on large landholdings, with much hand labor used in growing and harvesting the crops, and much machinery employed in their final handling, preparation for, and transportation to market. Wherever plantation agriculture has found a foothold in the tropics, it has made for both a fixed and denser population than was possible with primitive exploitation of soil fer-

Fig. 21. An agricultural scene in Stephenson County, northern Illinois. Though farms are here of moderate size, averaging about 127 acres, there is much use of labor-saving machinery in cultivation, harvesting, and for other purposes. Dairying, livestock, and cash-grain farming are most important in this region, in the order named, with approximately 40 per cent of all farms emphasizing milk production. Even in this area of slight relief or surface irregularity, it will be noted that the gentle slope of the foreground is planted in alternate strips on which corn, oats, sweet clover, and soy beans are grown. The flat land in front of the small village of Dakota, in the middle background, is in corn. Rural-farm population of Stephenson County is of moderate density: 21 persons to the square mile. This is more than twice that for the entire United States, but this is a better than average agricultural area, occupied for many years, and with good transportation facilities, including excellent roads. (Courtesy of the U. S. Soil Conservation Service.)

tility under much native use, though less dense than that under the Oriental system of intensive cultivation.

Populations Supported by Fishing. Wherever the land is inhospitable because of a harsh climate, steep slopes, thin and stony soils, or a combination of these conditions, it may not be profitable, or it may even be impossible to till the soil or engage in grazing, so the populations of such areas may turn to the sea for support. In bleak and inhospitable regions like Newfoundland and Labrador, for example, where the land offers few opportunities which afford a satisfactory basis for a livelihood, fishing is the most important occupation, supporting virtually the entire population, either directly or indirectly.

In other parts of the world, where climatic conditions admit of agriculture but where level land is limited in amount, as along the west coast of the northern portion of Honshu, the main island of Japan, fishing may afford either a full or a part-time occupation to supplement income derived from agriculture or some other source. In still other parts of the Orient, such as southeastern China, where population is extraordinarily dense, sometimes several thousand persons to the square mile, the land may not be able to afford support for all the people, so that many of them spend their entire lives afloat, living in boats which are their permanent homes. These people obtain their living from rivers, canals, and the sea, often practicing what is sometimes known as "aquaculture": the artificial propagation of fish, eels, and other aquatic "crops," as well as fishing for a livelihood.

In areas where fishing is the major basis for population support, numbers are generally few. Only in warm regions such as southeastern China, and there only with intensive use of the resources of both land and water, may locally dense popu-

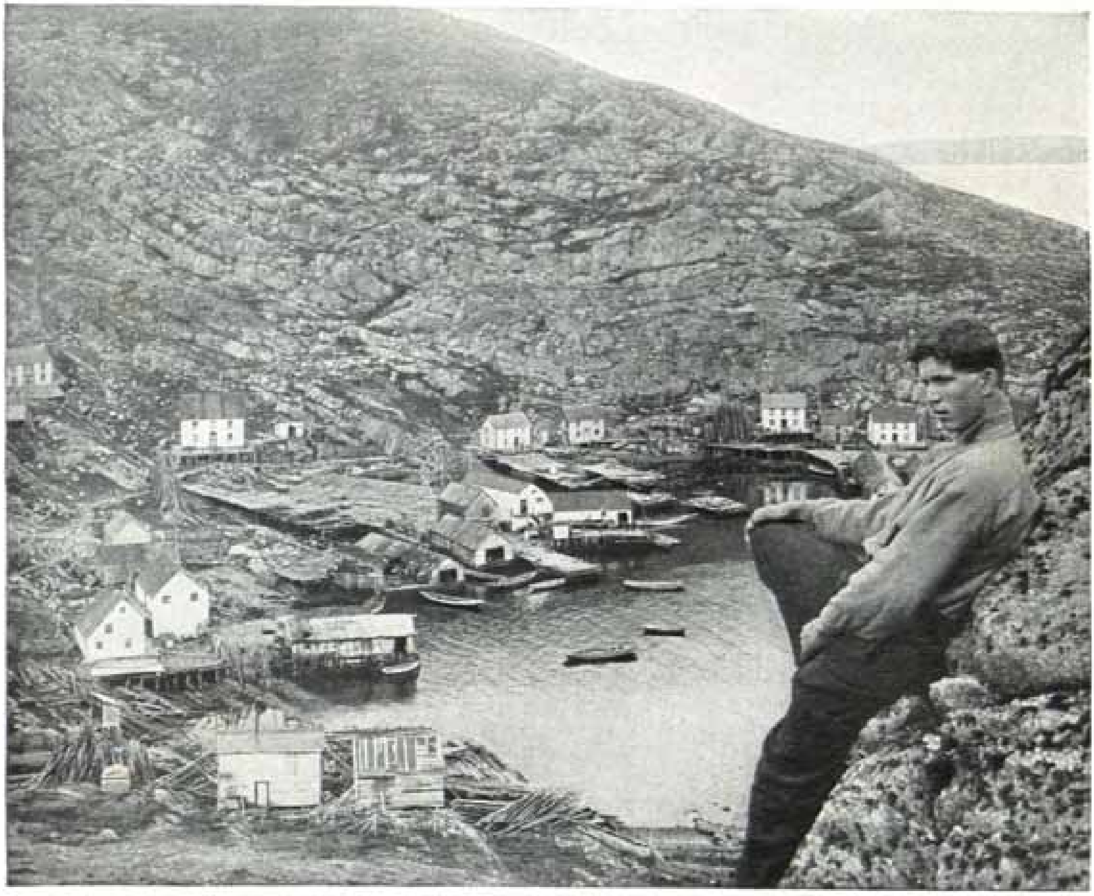

FIG. 22. A fishing village on the coast of Labrador, near Battle Harbor. The heavily glaciated upland is virtually destitute of soil; in this particular location, the bare rock forms the actual surface. Further, the climate of coastal Labrador is harsh. The sea, however, affords opportunity, for it abounds in fish and the fiorded or deeply indented coastline offers many harbors. Therefore the population of this area turns to fishing for support, though the returns are uncertain and the life is one of hardship and danger. The building back from the water's edge are dwellings; those along the waterfront are fish houses. The fishing boats are moored both alongshore and anchored out in the harbor. (Courtesy of the Keystone View Company.)

lations with very low standards of living be found. Everywhere, the pattern of population distribution is fixed, for it is tied to the sea or some body of water by the economic activity which ensures support.

Populations Supported by Forest Industries. Collecting wild forest products, lumbering, and other forest industries are normally of temporary importance only, if conditions are favorable for profitable agriculture. However, where slopes are steep, soils are poor or thin, or climatic conditions are generally unfavorable for cultivated crops but satisfactory for tree growth, one or more of the forest industries may serve as the basis for man's support for considerable, or even long periods of time.

Thus the Fang of the Congo basin obtain their living in part from the forest and in part from their gardens in the clearings. When work is unnecessary in their small cultivated fields, they go "ebonying," cutting down and splitting up the trees, and transporting the pieces to their villages. There the ebony will later be exchanged for needed manufactured goods.

In the Puget Sound region of the United States, where few of the more profitable crops can be grown to advantage because of the cool, damp, foggy weather, the valuable forest of Douglas

fir, spruce, and other species supports a forest industry of both great relative and actual importance. Other parts of the world which offer only limited agricultural opportunity, such as parts of southeastern United States and northern Eurasia, both European and Asiatic, depend in similar fashion on their forests as important sources of income.

If exploitation of the growth of years is the practice, as is common in most American lumbering operations, returns may be high, but temporary; population density will be low; and the inhabitants will shift from camp to camp with change of location of the lumbering operations. Even where the forest industries are the principal or an important basis for support over an extended period of time, the number of inhabitants is never great, for the returns per unit of land in forest crops are always low. If occupancy is based on use of the forest as a long-time asset, however, settlement may be relatively fixed in location.

Populations Supported by Mineral Industries. Wherever deposits of iron, copper, gold, silver, coal, or other minerals, either metallic or nonmetallic, occur in quantities and under such conditions that they can be extracted economically, mining may be an important and sometimes almost the only industry. This is frequently true in highland areas such as portions of the mountainous western states of the United States. In some of these, rainfall is so light that important forests are lacking; pasturage is so poor that grazing will support few inhabitants; and the amount of water available restricts agriculture to limited areas. Again, these highlands have cool to cold nights and many crops do not thrive under such conditions. Markets are also far away and the high cost of transportation makes it impossible to grow and dispose of certain crops at a profit. Thus min-

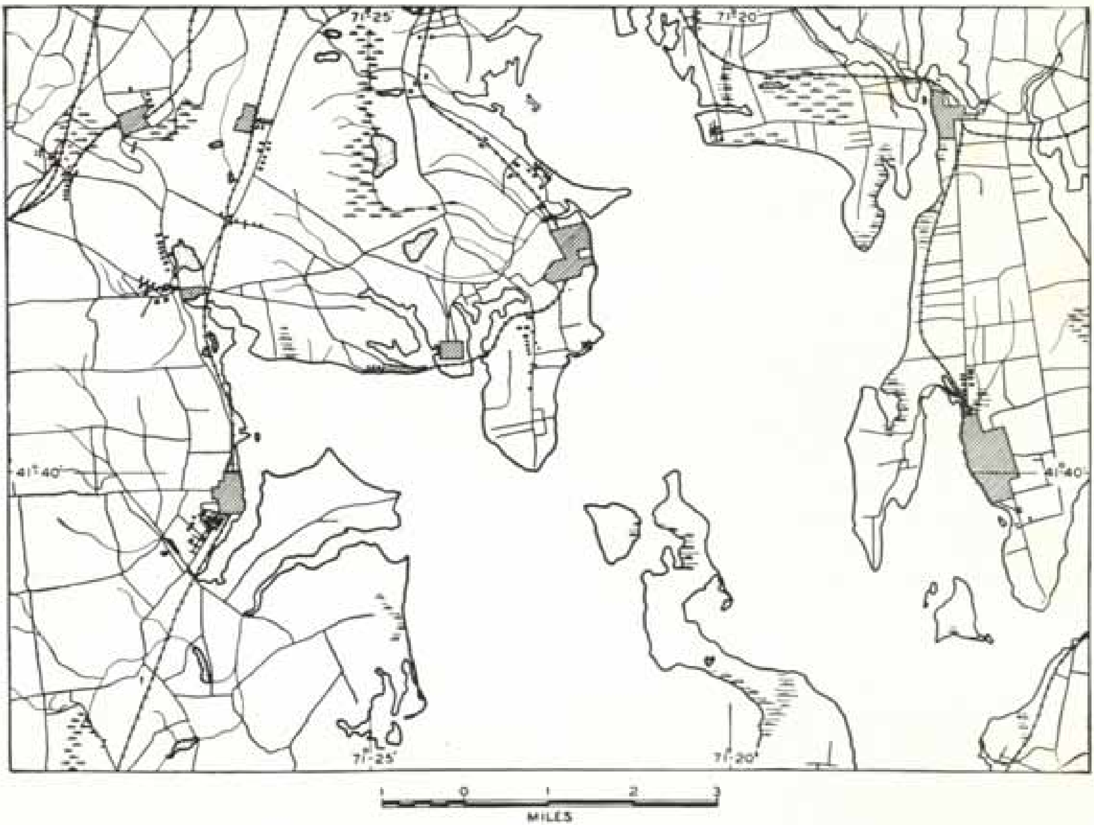

FIG. 23. Distribution of population in the Narragansett Bay region of Rhode Island. It will be noted that most of the houses are grouped in villages or smaller aggregations. This is typical of conditions in Rhode Island, where only 1.5 per cent of the total population live on farms.

ing often assumes great relative, and sometimes equally great actual importance in such areas.

Mineral wealth and mining are not, of course, confined to highland regions, for valuable deposits, particularly of the nonmetals, frequently occur in lowlands. In such areas, however, though mining may actually be more important than in many highlands, it is normally a secondary economic activity because of the greater local importance of other occupations such as agriculture, industry, and trade.

Populations supported by mining are concentrated where the mineral wealth occurs. This determines the pattern of occupancy, which is likewise normally related to drainage lines in highlands, inasmuch as feasible locations for settlements, roads, and rail lines are afforded by valleys. In an area where mining is the sole basis for support, density of population will never be maximum, except locally, but it may vary from sparse to more than average, dependent on the kind, size, accessibility, and other characteristics of the mineral occurrence. The life of communities without basis for support other than mining is limited by the size and richness of the mineral deposit, and the rapidity with which it is exploited. Many are very short lived; relatively few maintain their existence for long periods of time.

Industrial and Commercial Populations. There is little specialization of effort among primitive populations, nor was there among the early pioneers of this country. In such societies, each man engages in a variety of pursuits: obtaining his own food supply; building his own house; fashioning his own implements; and making his own clothing, largely by his own unaided efforts. Only as population increases in density does any considerable specialization of effort occur. This is accompanied by progress which causes multiplication of wants, so that exchange of local products for materials or articles, which cannot be or are not produced in the home area, becomes important. To carry on the extensive trade or commerce of advanced populations occupies the time of many individuals, who derive their support, either wholly or in part, from such activity. With initiation of trade, materials from other areas, as well as those of local origin, become available for fabrication, and if, sources of power are present and labor and other conditions, including marketing facilities, are favorable, manufacturing may become the most important occupation of the population. This is the case in southern New England, where a large percentage of the people support themselves by working in factories. For example, the total population of the small state of Rhode Island, which has a land area of only 1058 square miles, was approximately 783,000, or nearly 734 persons to the square mile, in 1947. It is obvious that agriculture could not support such a large number, with normal American standards of living and farm practices; investigation discloses that the rural-farm population was only 1.5 per cent of the total. The remaining 98.5 per cent of the inhabitants lived in small communities, or in incorporated places with populations of 2500 or more, and supported themselves largely by work in factories. This same condition, or one very similar, obtains in most of southern New England; in much of northeastern United States; in the densely populated regions of western Europe; and even in the Orient, in certain portions of southern Japan. That great density of population characterizes industrial areas everywhere may be noted by reference to Figs. 5 and 14. Such areas are likewise ones of relatively fixed population and marked urbanization.

QUESTIONS AND EXERCISES

1. In what respects do the stage of man's development and his economic activities affect population? Why is an understanding of these effects of value? What types of economic activity are today the basis for support of dense populations?
2. Why must the total population of the earth have been small during prehistoric times? How has human progress made the support of larger numbers possible? What will the future probably develop along that line?
3. What types of area are still unoccupied at man's present stage of development? What may make the occupation of such areas a possibility in the future?
4. Name some migratory hunting and fishing populations of high, low, and intermediate latitudes. What are the characteristics of the areas in which they live? How do they make a living? Are populations sparse or dense? Why? How distributed? Why?

5. In what parts of the world is pastoral nomadism most important today? Why? How does pastoral nomadism affect population density and the pattern of population distribution?
6. In what respects does commercial grazing differ from nomadic herding? In what areas is commercial grazing most important? What are some of the characteristics of these areas? In what respects do population densities and distributions differ with these two uses of grassland areas?
7. Name the principal occupations which serve as the basis for man's support. Of these, which supports the largest fraction of the world's present population? Is this fraction larger or smaller than it was 1000 years ago? Why? Name the economic activities of your home area in the order of their relative importance.
8. Compare and contrast the practices and other characteristics of primitive tropical, plantation, Oriental, and Occidental agriculture. How do population densities and patterns vary with these different types of agriculture? With which one of these types is support of the densest population possible? Why?
9. Under what conditions do populations turn to the sea for support? What are the population densities and distributions in those areas where fishing is the major economic activity?
10. What types of forest use serve as the basis for man's support? What population density is each able to support? Under what conditions is such support temporary? Relatively permanent? What patterns of population distribution prevail in areas where the forest industries are the dominant economic activities?
11. What factors affect population densities in areas where the mineral industries assume great relative importance? In such areas, what factors affect the pattern of population distribution?
12. What economic activities support the densest populations in Occidental areas? What peculiarities of population concentration exist in such areas?
13. Why do the occupations of any area tend to change with the passage of time? Illustrate by changes in your home area. Have these changes affected population density and distribution? In what respects, if any?
14. In what parts of the world are changes in economic activities occurring at present which will affect population densities or distributions? What will be the effect of such changes on the populations of other countries, as well as that of our own?

SELECTED REFERENCES

Huntington, Ellsworth, *The Human Habitat*, D. Van Nostrand Company, Inc., New York, 1927, Chaps. II–VII.

The six chapters suggested for reading are concerned with where people dwell and the effects of geographic extremes on man, as manifested in desert borderlands, lands which are too cool, and those which are too warm and moist. The treatment is clear, interesting, and supplies illustrations which will amplify the discussion in your text.

Vidal de la Blache, P., *Principles of Human Geography*, Henry Holt and Company, Inc., New York, 1926, Part I, Chaps. III–VI; Part II, Chap. III.

The four chapters of Part I treat the great population agglomerations of the present; the chapter in Part II deals with means of sustenance. Presentation is clear and interesting, and should be both an aid to understanding the present and provocative of thought as to the future.

Chapter Five

POPULATION CHANGES AND POPULATION PROBLEMS

Increase of the World's Population. One of the significant facts associated with man's occupation of the earth is his great increase in numbers. This has been particularly marked since the beginning of the preceding century, for, since then, they have doubled. Moreover, this increase has not been confined to white populations. In fact, within recent years, it has been more striking among colored peoples, India added more than 50,000,000 during the past decade; increase in the number of Chinese during the same period, though not known exactly, was probably even greater. In Japan, the number of inhabitants mounts steadily at a rate of somewhat less than a million yearly, or nearly 3000 each day. Such increases constitute a threat to the balance between population and resources; to maintenance of satisfactory standards of living in the areas where they occur.

Stage of Development and Population Change. Stage of development affects both total numbers and population composition. Among primitive societies, dependent on collection and the chase for support, birth and death rates are practically equal, and population remains essentially stationary over extended periods of time, with numbers in the older age groups relatively small.

By contrast, initial agricultural use of the land, or an immature agricultural economy based on either Oriental or Occidental practices, tends to ensure an increasing population. Such immaturity sometimes results from use of only part of the potentially arable or productive land, and the existence of an agricultural frontier. Again, it is due to undermechanization and the need for large numbers to grow and harvest the crops. Which of the two it may be is immaterial, insofar as the effect on population growth is concerned; either presents opportunity for the support of additional numbers. Therefore large families will be the rule and population growth will occur, even to the extent that it persists during the initial stages of shift to a predominantly industrial basis for support.

During the earlier stages of industrial development, then, population continues to increase, as it is doing today in Japan. With greater development of this type, however, urban development and rising standards of living are accompanied by smaller families. Eventually, this leads to a stationary population, or even decreasing numbers.

Population Changes in Europe. All these rates of population growth are represented in Europe. The first occurs among the hunting, fishing, and pastoral peoples of the Arctic tundra, the treeless plains bordering the polar seas. The second still persists in the southern and southeastern parts of the continent, and in the U.S.S.R. The third stage has been reached in the highly industrialized regions of central and western Europe.

Before the present extensive development of industry in Europe, the population of the continent increased so rapidly that not only did the total number of inhabitants more than double, but a surplus was available to people other areas. At the present time, however, this surplus has been replaced by a deficit in those parts of central and western Europe where agriculture has been supplanted by industry as the support for most of the people.

Hence, for Europe as a whole, the rate of population increase was considerably smaller during the decade ending in 1940 than during that terminating in 1930. In both decades, it was least in the central and northwestern regions, somewhat greater in the south, still greater in the east, and probably greatest in the U.S.S.R.

Though the effects of the war are difficult to evaluate fully, they will probably hasten the process of population loss in much of Europe.

The population changes for several of the countries of Europe are shown in Fig. 24, in which both past conditions and probable future trends are indicated. In France, Germany, England and Wales, and Italy, populations are due to decrease. It is estimated, for example, that by 1976 the total population of the British Isles will be reduced to 32,000,000, only about 70 per cent of that of the present. The only nation of the Western world, indeed, which still has a large, fast-growing population is the U.S.S.R. There, the transition from agriculture to industry is still in its initial stages and the past history of the nations of western Europe is being repeated. During the 12 years ending in 1939, population increased 16 per cent in the Soviet Union, and, during that same period, the number of farmers decreased by 6,000,000, as a result of the trek to the cities which accompanied industrial development. Today, nearly 50 per cent of all the inhabitants work in factories.

Probably even more important than the change in numbers is the one which is occurring in the relative size of the constituent age groups in European countries. Even today, only the U.S.S.R. has a *young* population; elsewhere the older age groups constitute an ever-increasing percentage of the total population, and the war will probably hasten this change, except in the Soviet Union, where the birth rate has risen greatly of late.

Probable Future European Populations. If the population trends in European countries are studied, it becomes apparent that only Soviet Russia promises to enjoy a great growth in the number of its people during the next quarter of a century. By 1970, that country will have at least 220,000,000 and probably 250,000,000 inhabitants, for approximately 80 per cent of all population growth to be expected in Europe between now and that date will be in the Soviet Union. Elsewhere, in fact, numbers will reach their peak not later than 1960; by 1970, a decline will have set in. France, for example, will then have 4,000,000 fewer inhabitants than in 1940; Great Britain will likewise have suffered a loss of population; Germany will not be gaining in numbers.

These differences in growth rates are related to the age structures of the populations of the various countries. Only in Russia are there more children under five years of age than individuals

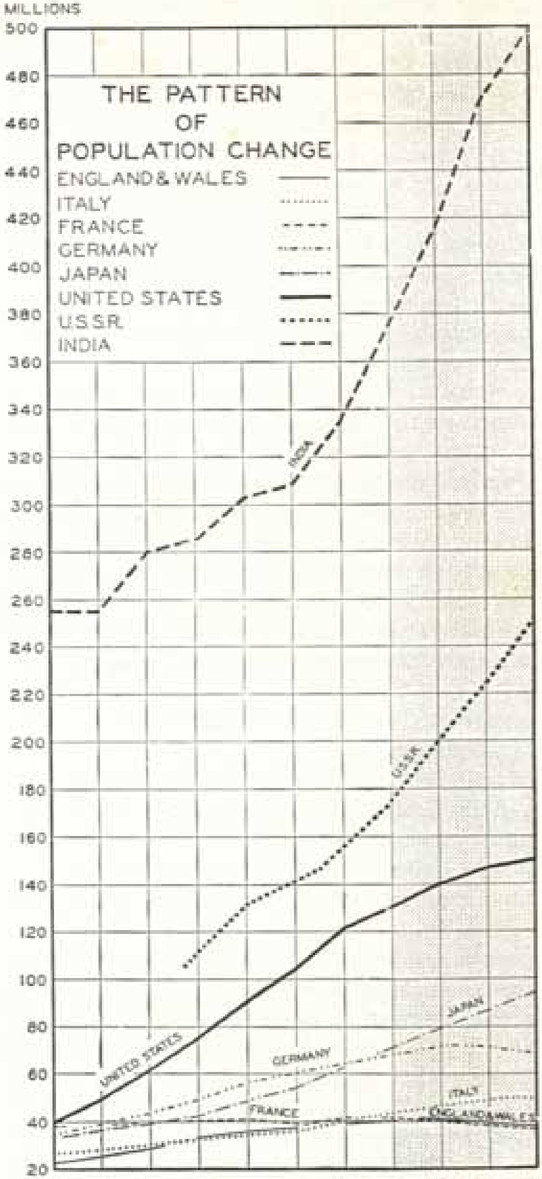

FIG. 24. This graph shows the population changes which occurred in several countries between 1870 and 1940, and projected changes from 1940 to 1970, disregarding the effects of the war and the possibility of internal migrations. It will be noted that, for most white populations, the period of rapid growth is almost over. (Based on studies by the Office of Population Research, Princeton University.)

in any other age group. By 1970, it is probable that there will be almost as many people over sixty-five as under fifteen years of age in the countries of central and northwestern Europe. These facts indicate that Russia will, by 1970, emerge as by far the most populous country of the Western world, with both ample room and adequate natural resources to permit of expansion and great development. The potentialities of this are apparent, and of interest to us, as well as to the countries of Europe, for the Soviets through their Asiatic landholdings are one of our near neighbors.

Spread of European Populations. For many centuries, the lands known to populations of the Western world were limited to those which bordered the Mediterranean Sea. From this center, around which early Occidental civilizations developed, the known world expanded gradually in all directions, as returning travelers and merchants described the distant regions they had visited. It was not until near the close of the fifteenth century, however, that discovery of the Americas by Columbus led to knowledge of the New World, and it was still later before additional exploration revealed the true extent and outlines of the world's land masses in their entirety.

With increasing knowledge of the opportunities presented by new and distant areas, European peoples spread into these faraway lands, producing important changes in the areas invaded. The most notable of these shifts of white populations to the cooler parts of the earth's land surface occurred during the past, and early in the present century, as an accompaniment of a better knowledge of favorable natural conditions in the United States, Canada, Australia, and New Zealand, and of improved means of transportation and communication. Since the population of Europe doubled during this same period, this, also, was undoubtedly a contributing factor. This movement was most marked, and the number of arrivals in the United States was greatest, between 1880 and 1930. Between 1900 and 1920, when most rapid, immigrants numbered 9,000,000; in all, they totaled approximately 30,000,000. Similar though smaller migrations to Canada, Australia, and New Zealand occurred during essentially the same period.

Of late years, whites have also invaded the tropics, principally as overseers of native or imported labor on plantations, or as managers of other business enterprises. A few have also moved as permanent settlers to work the land, as in Queensland, in tropical Australia. Though the numbers involved in these movements to the lower latitudes have not been great, the effects produced have been important. With the establishment of plantations, opportunities for gainful employment have increased, and in many instances such ventures have also widened markets for native production and enabled support of denser native populations. Then, too, white control has tended to eliminate earlier practices which kept population in check. Therefore, in Java for example, the native population has increased from an estimated 3,000,000 or 4,000,000 in 1850 to nearly 50,000,000 at the present time. Further, in those areas where the local supply of native labor was inadequate, there has been an importation of large numbers of colored workers from more densely inhabited near-by warm regions. This has produced not only a change in man's distribution, but an admixture of peoples as well, and has created new population problems.

Whether the earlier great migration of white population to the cooler parts of the earth's surface will be matched by a comparable invasion of the tropics at a later date is still uncertain, though it is generally conceded to be improbable. In part, this is because whites may not be able to adjust themselves to the conditions of humid areas with prevailingly high temperatures; in part, it is because the best parts of such areas already have large native populations, with standards of living so low that whites cannot meet the competition successfully. Even for tropical Australia, in Queensland, where such competition is not encountered, there is some difference of opinion as to the degree of success achieved by white colonization.

Population Changes in Asiatic Areas. Approximately 75 per cent of the world's inhabitants live in Eurasia; more than 50 per cent in Asiatic areas alone, excluding the U.S.S.R. Therefore even small perecentage increases of population in Oriental agrarian areas, where numbers increase up to the limits of subsistence, produce large numerical accretions. There, any slight decrease in the high death rates, improved agricultural practices, or industrialization, is accompanied by the addition of large numbers. Because of the present immature agricultural economy of most Asiatic areas, such increases promise to

persist for several decades. Only in Japan, which is in the earlier stages of industrial development, will population probably tend to become stationary within the next three or four decades.

Thus, in agricultural India people continue to multiply at a disturbing rate. For the half century ending in 1941, the increase was 109,000,000, or more than 20 per cent. This resulted from a high birth rate, more than twice that of the United States; it was not greater only because of the low life expectancy at birth: slightly less than 27 years. With present birth rates, and death rates at the level of those in the United States, it is estimated that the population of India would become four times the world's present total in less than a century. The present restricted, though enormous increases, are made possible only by construction of additional irrigation dams, swamp drainage, and some improvement of agricultural practices. Yet, despite these, famines still take their toll in this densely inhabited region.

The enormous population of India has led to great overcrowding in some parts of the country. Locally, in Bengal, where the average density is 646, there are limited agricultural areas where there are 3278 inhabitants to the square mile. This is about one person to an average city lot. However, densities fall far below this figure in many parts of India. The Native States, for example, have only 114, as contrasted with 248 inhabitants per square mile for British India, and some of the provinces have even fewer than either of these numbers. Though some migration to the underpopulated areas has developed, it has not been extensive, and cityward movement has likewise been small. Therefore the population problem of India is still unsolved and promises to be serious for some time to come.

The total population of China is not known definitely, for no accurate enumeration of the inhabitants has ever been made. Like that of India, however, it is very large, probably in excess of 450,000,000, agrarian in type, and increasing rapidly. In some areas, densities reach almost unbelievable figures; in others, in the northwest and south, they are much more moderate. Northwestern China, for example, with an estimated 41.2 per cent of the land area, supports only about 5 per cent of the total population of the country. As in India, the population problem will probably persist for several decades because of the present stage of development, and the probable slowness of change in the basis for support.

The four main islands of Japan are probably more densely occupied than any other whole country of Asia, though small areas of India, China, and Java are as badly congested. Today, the average population density in Japan is estimated to be nearly 3000 persons per square mile of arable land. Further, population increases steadily. It more than doubled during the century ending in 1940, and it still increases at an average rate of 920,000 each year. However, in Japan as in the West, a declining birth rate has accompanied increasing industrialization, urbanization, and rising standards of living. Between 1915 and 1935, the growth of the cities equaled the entire national increase in numbers. Today, at least 50, and possibly as much as 60 per cent of the total population is urban, largely as a result of the cityward movement from rural areas. Therefore a gradual slowing up of population increase may be expected, to last until at least 1970. By that date, or shortly thereafter, population will probably become essentially stationary. This is disregarding any effects the war may produce, as these are unpredictable at present.

Probable Future Oriental Populations. Present populations are both large and growing rapidly in certain countries of the Orient. These are India, China, and Japan. Of the three, the first two have relatively young populations, and, though that of Japan is aging somewhat, it will be some time before it will become stationary, and still longer before an actual decrease in numbers may be expected.

In China, where industrialization is still in its beginnings, potentialities for development are much greater than they ever were in Japan. This is true both because of the number of inhabitants and natural resources, including one of the world's greatest reserves of coal: a source of power. Therefore it is almost inevitable that the Chinese will realize on these assets in the relatively near future. When this occurs, it will affect the rate of population increase.

India, also, whose present population of at least 400,000,000 is increasing at a rate of several millions each year, already has an important iron and steel industry, based on local raw materials, as well as other industries with promising futures. What effect recently attained independ-

ence will have on the growth of industrialization and population numbers is uncertain, but there are many portents of great change to be expected in this old-settled area with its enormous population.

Within a few decades, industrialization raised Japan from a condition of inability to resist dictation by the great powers of the Western world to a place of importance among the nations. Similarly, both China and India, with their rapidly growing, relatively young, and enormous populations, may logically be expected to play a much more important part in world affairs than they have in the recent past. Already it is apparent that white domination and colonial empire, as we have known them in the Orient earlier in the present century, are destined to disappear. When this occurs, it will mark the end of the undisputed supremacy, though not necessarily that of the influence, of white populations in eastern and southeastern Asia. Moreover, it will increase the importance of our frontage on the Pacific Ocean, thus adding another to our long list of favoring natural conditions.

Population Changes in the United States. During the 150 year period ending in 1940, the population of the United States increased slightly more than thirty-threefold, and the density per square mile nearly tenfold. In part, this increase in numbers resulted from an excess of births over deaths in an area which was predominantly agricultural during the earlier decades; in part, from an almost unprecedented emigration from European areas of surplus population until quite recently. During the seven decades between 1790 and 1860, the percentage increase per decade

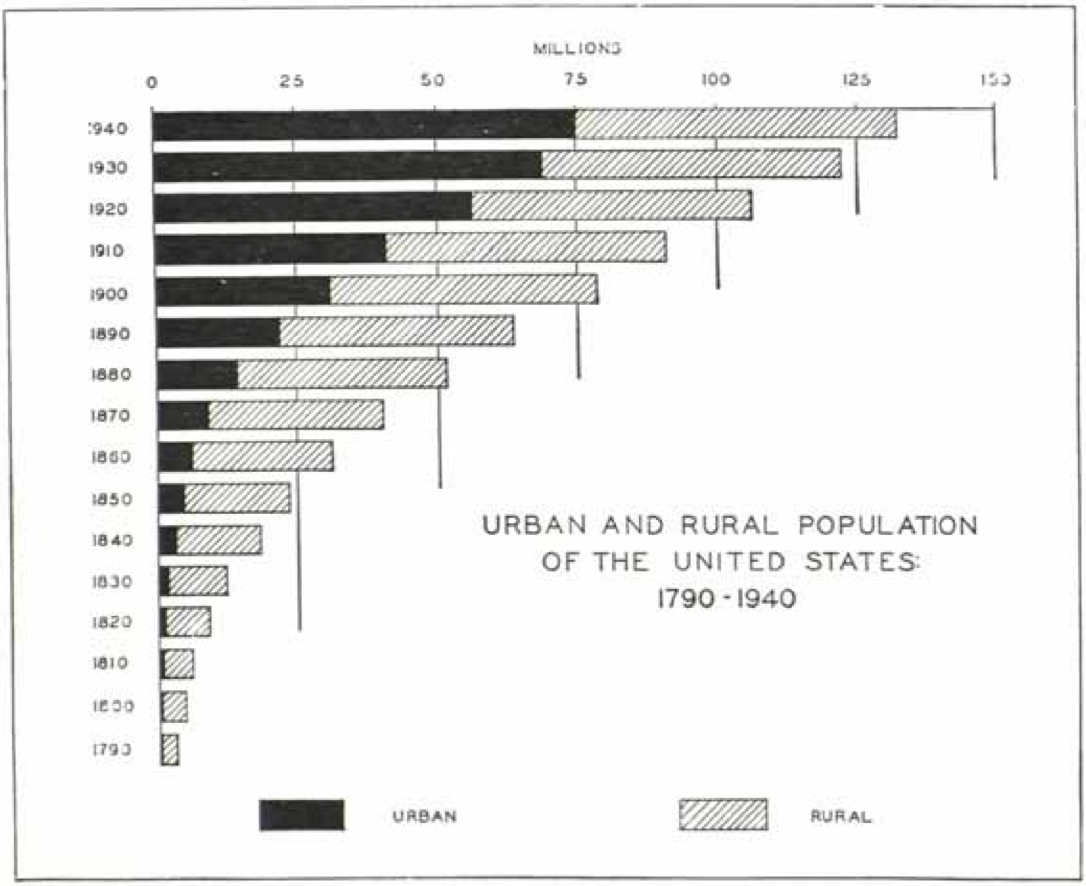

FIG. 25. This graph shows that the rapid growth of total population in the United States between 1790 and 1940 was accompanied by a marked decrease in the percentage of the rural, and a striking increase in that of the urban component of the population. (After the U. S. Census.)

never dropped below 32; in four of the seven, it amounted to 35 per cent. Even since 1860, though percentage increases have been smaller, numerical increases have ranged between 7,000,000 and 17,000,000 for each decade; for five out of the eight, they have exceeded 12,000,000. During the decade ending in 1940, however, the percentage increase dropped to 7.2, the smallest in our history; the numerical, to 8,894,229, the smallest since 1850. Temporarily, this trend has been reversed, it being estimated that the increase for the decade ending in 1950 will exceed 13,000,000.

These changes in numbers and rates of increase which have been noted have been accompanied by changes in composition of the population. During the earlier periods of American history, both the numbers and the percentages of the total population living in urban centers were small. Even as late as 1880, only 28.6 per cent of the population was urban, and it was not until 1920 that the number of people living in urban centers exceeded that of those living outside of the cities. By 1940, however, the rural was less than 50 per cent of the total, and only 77 per cent of the urban population.

In addition to this shift from rural areas to urban centers, there has been a decrease in farm population for several decades. The U. S. Department of Agriculture estimates that by January, 1944, farm population was only 25,521,000, about 19 per cent of the nation's total, and aging rapidly. The same bureau also estimates that, during the five-year period ending January, 1944, the farms lost 4,748,000 persons, 15.7 per cent of their total population. Some of this loss in numbers may be temporary, it is true, but much of it will be permanent, for even with fewer farmers production has increased. Therefore, taking all the facts into consideration, it is improbable that the *farms* of this country will ever again support the populations of the past, even though the numbers living in rural areas may increase as a result of decentralization made possible by improved means of transportation.

The history of population change in the United States illustrates the varying conditions which characterize different stages of development. With an agrarian economy and an agricultural frontier of great promise, population grew rapidly, by both natural increase and immigration. With disappearance of the agricultural frontier and initiation of industrial development, numerical, though not percentage increases of population, became even greater. But, with further industrial development, increased urbanization, and much higher standards of living, both numerical and percentage increases of population lessened to the extent that it was estimated numbers would become stationary or even decrease by 1970, or shortly thereafter. As has been noted earlier, this trend has been interrupted during the past few years, though this is probably only temporary.

It should be noted, however, that the change in rate of population increase from decade to decade has not been uniform throughout the United States. This will be evident after study of Fig. 26. In dominantly rural areas, growth still continues; in others with a high degree of industrial development, this may not be true. Even where growth occurs in such areas, it may be a result of migration from regions of surplus population rather than increase resulting from an excess of births over deaths.

Since the war has produced some decentralization of industry and a spread of the effects of industrial development, the conditions shown by Fig. 26 may be modified considerably during the decade ending in 1950. Therefore certain areas which were not affected materially by the factory type of development prior to 1940 may, by 1950, show important change in total population, rate of population increase, and composition of population by age groups. This is already evident in California, for example, where an estimated 39.5 per cent increase over the 1940 population had occurred by January, 1947.

Studies of Indiana population growth by S. S. Visher illustrate what has occurred over much of northeastern United States. Of the 92 counties of Indiana, only 16, most of which have relatively large cities, have increased steadily in population, decade by decade; the others have suffered losses. The counties which have lost heavily are of two classes: (1) those where agricultural or other use of natural resources has lessened opportunity to the extent that families are fewer in number; and (2) good agricultural areas with aging populations, small families, and mechanized production. As in much of northeastern United States, agriculture is no longer the most important economic activity of the inhabitants of Indiana; in 1940, only 23.7 per cent of

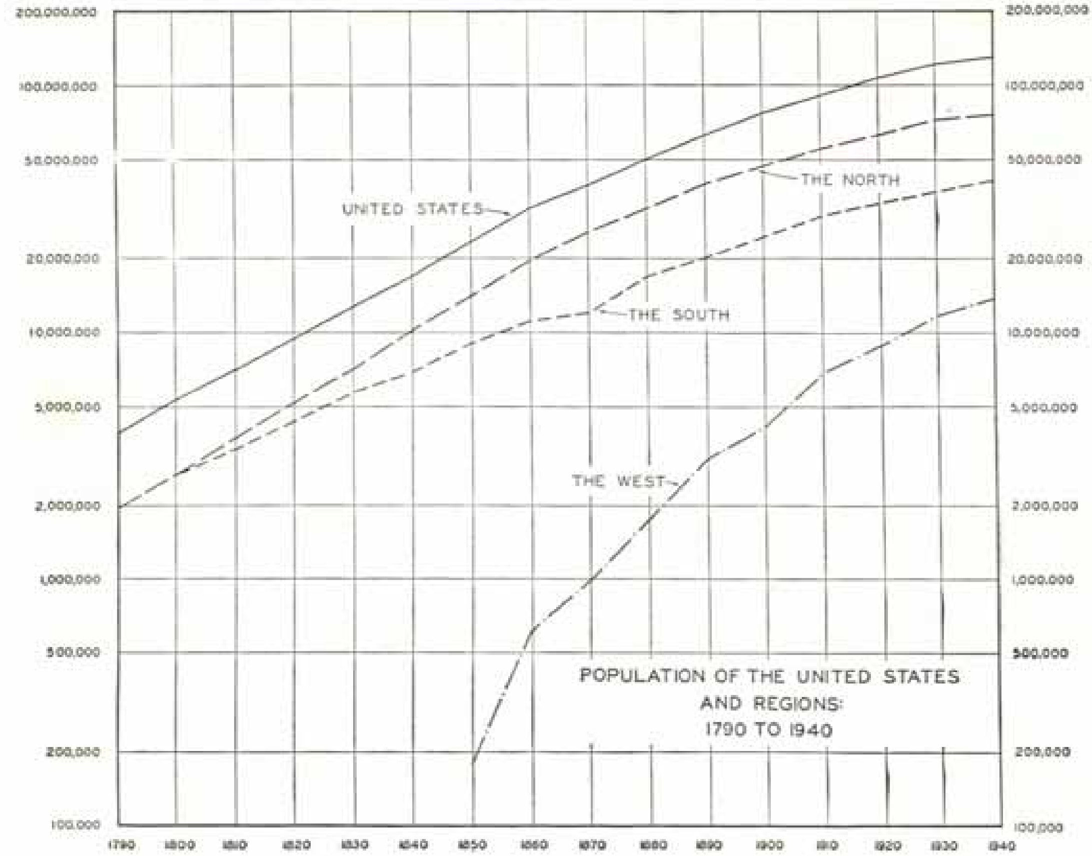

FIG. 26. This graph shows that the rate of population growth has not been uniform throughout the United States, but has varied from region to region. In some areas, it began early and has nearly ceased; in others, it began late and still continues. It should be of interest to consider the reasons for these differences. (After the U. S. Census.)

the population lived on farms. Stimulation of industrial production by the war will, there as elsewhere, have a definite, though not definitely predictable effect on postwar population growth in the state.

Population Surpluses. Since even slight increases of population may upset the balance between local resources and subsistence, they were often the occasion for raids on more fortunate areas, or even for mass migrations during past periods of history. To the first of these two classes of population movement, temporary in character, belong incursions of desert-dwelling nomads, such as the Bedouins of the Sahara, on sedentary populations of oases. To it also belong pillagings of the coasts of southwestern and southern Europe by Scandinavian Vikings. Examples of the second class of movement are afforded by the irruptions of warlike pastoral nomads from the steppes or grasslands of central Asia, especially during dry years when pastures failed: to the east into the plains of China; to the west, into European lowlands.

In planning for the postwar future of the more than 2,000,000,000 people of the world, present inequalities of population distribution have led to consideration of the desirability of some resettlement. But where! There are no great, relatively vacant areas of promise, as in the past, and today, though population is "less fixed than national boundaries," its movement is neither free nor unrestricted.

Even if free, the unrestricted migration of Indians, Chinese, and Japanese would only substitute equally serious problems for the present one of local overpopulation in India, China, and

Japan. For example, if Australia, with its present small and essentially stationary population, were opened to Indian immigrants, it would provide an outlet for the natural increase of India for not to exceed five years. Thereafter, Australia as well as India would have an overpopulation problem.

Since migrations on a large scale are neither politically nor economically desirable in a "broken world," wholesale shifts of population, which are inevitably bound to produce undesirable results, are to be avoided. Further, civilized man has devised possible alternatives; not only for pillage and loot, but for large-scale population movements as well, which should eventually afford relief from local congestion and may finally effect a permanent cure.

As a result of thinking along economic, historical, and other lines, based at least in part on the facts of geographical conditions, some believe that industrialization may solve the problem of overpopulation by reducing birth rates and increasing productivity. This would make for more to divide, and smaller numbers among which to make the division, thus meeting needs effectively. Others fear that such a development, now beginning in certain Oriental areas, threatens the future of the white races. Still others point out that a solution effective among white populations may not meet the necessities of Orientals, with their taboos and traditions. Further, it should be kept in mind that industrialization of the Western world occurred at an earlier period of history and stage of world development, when large areas were still sparsely occupied and unexploited. It is apparent that no plan, satisfactory to all and certain of success, has been promulgated as yet.

Some Effects of Population Distribution. Population distribution affects both the range of effective economic activities and potential returns. A sparse population precludes the possibility of either extensive trade or industrial development, which offer great and varied opportunity to man. Only where there is considerable or great population density, though not always even there, is maximum diversification of economic activity possible. It is, of course, true that concentration of population does not necessarily ensure diverse economic activities; it is only one factor which makes them possible. Thus, though the population of China is dense, the amount of trade is relatively small, except for local exchange, and there is only limited industrial development of the Western type.

The United States, with both vast natural resources and a large and sufficiently dense population in its more promising areas, offers a peculiarly favorable setting for both the present and continued development of many effective economic activities. Therefore we should not view the future with foreboding, simply because the agricultural frontier has disappeared. We should, instead, realize that the future offers much greater opportunity than was ever presented by the wilderness and its "free land."

Size of population likewise affects both national influence and security. Though relatively small, aggressive groups were often a continuing threat to the peace and possessions of the generally numerous, but less warlike inhabitants of more favored areas during the earlier periods of history, this is no longer true. Today, when war involves all the people of a country, only the larger population groups can be a serious menace to world peace, and these only if united, fortunate in natural resources, and industrialized, for all these factors affect military potential.

This necessity for a large population, if a nation is either to defend itself successfully or to embark upon a program of aggression, is recognized in the concern manifested when a declining birth rate foreshadows stationary or decreasing numbers. It is apparent that, though a large population does not, in itself, guarantee territorial integrity, as illustrated by China, it is still a prerequisite for such security. Therefore such small nations as may continue to maintain their separate existence must do so only by the sufferance of their larger, more populous, and powerful neighbors, of whom they tend to become economic satellites.

In addition to being unable to defend its territorial holdings successfully, a nation finds it impossible to command an important place in the councils of the family of nations, unless its population is large. Even large populations may meet with difficulty in having their wishes respected and their recommendations accepted, in this day and age. This is because advice, unless backed by the power of enforcement, is seldom considered of importance in international affairs, unless in the interest of those able to implement words by action, if necessary.

The implications of these facts, as they affect

the United States, are obvious. Fortunate are we that our population is large, and doubly fortunate that natural opportunity has made possible a commercial and industrial development so great as to be envied in less favored areas. With wise leadership and use of this power, our country is not only in a position to protect itself against aggression, but to assume an important place in world affairs as well.

Importance of Population Factors as a Basis for National Planning. The preceding consideration of population factors is an attempt at a realistic appraisal of *existing* conditions in an *imperfect* world. Even though limited, it should suggest that both population performance and potentialities are facts on which any effective planning for the future must be based, at least in part. Therefore it is vital that, in formulation of both our domestic and international policies, due importance be accorded the part populations play at present, and promise to play in the future.

QUESTIONS AND EXERCISES

1. What is the present population of the world? Is it increasing or decreasing? How rapidly? Is the rate of increase uniform in all areas? In all parts of the United States? In all parts of your home state? Why? In what parts of the world is population increase most rapid at present? Why? Why do such increases cause great concern?
2. Into what parts of the world was movement of white population most rapid after discovery of the Americas, and of sea routes to the Orient? Why? Will this movement be paralleled at a later date by a similar invasion of the tropics? Why?
3. What effects have been produced by the present movement of white populations into the tropics and the establishment of tropical plantations? Which of these are beneficial and which are detrimental?
4. What effects do the different stages of development of man have on population numbers and composition? Illustrate by examples of definite areas with each of these stages of development.
5. In what stages of development is the population of Europe at present? What does the future hold in the way of changes in present European populations? In which one of the European countries does population promise to increase most rapidly in the future? Why? How will the war probably affect European populations? Why?
6. What does the future probably hold in store in the way of population changes for Asiatic countries such as China and India? Will white influence probably increase or decrease in these countries after such changes have occurred? Why? In what respects would the emergence of great nations on the borders of the western Pacific be of importance to the United States?
7. What is the present population of Japan? Its area? How does the population density compare with that of other countries? For how long has the population problem of Japan been serious? Why is it of rather recent origin? Will it disappear in the future? Why? How has industrial development affected it?
8. Discuss the changes in number, distribution, and composition of the population of the United States between 1790 and 1940. What changes will probably occur by 1970? Will these be beneficial or detrimental? Why?
9. Why are problems of local overpopulation difficult of solution? How were such problems solved in the past? Why can they no longer be solved in those ways? Why is free migration of population impracticable today? What solutions of the problems of local overpopulation have been proposed? What are the objections to such solutions?
10. How does population density affect the possibility of diverse economic activities? Why? What is the actual effect of population density on diversity of economic activities? Illustrate by examples of specific areas.
11. How do numbers of population affect national security and influence? Illustrate by examples. What does the future hold for the United States, insofar as the future will be affected by population numbers and distribution?
12. To what extent should population trends and characteristics be considered in national planning? Why?

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This monograph supplies a comprehensive and excellent treatment of white settlement in the tropics. It includes a consideration of the problems

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PART THREE. MAN AND ENVIRONMENT

Chapter Six

THE ENVIRONMENT: ITS FACTORS AND FUNCTIONS

The Landscape and Its Features. The observable features of any region occupied by man are of two types: (1) those persisting from a period prior to human occupation; and (2) those resulting from such occupancy.

Those not resulting from man's occupation and use include space relationships, climate, topography, soils, ground water and natural drainage, mineral wealth, contact with the sea, and life forms, both plant and animal. It should be remembered, however, that present conditions of certain of these individual features of any inhabited area represent an inheritance modified by man's activities. Therefore the appearance of the landscape of today for any given region may, in some respects, bear only a slight resemblance to the original one, from which it has been derived.

Those aspects of the landscape which result from human occupancy embrace such items as buildings; roads, railroads, and other means of circulation and communication; fences and other boundaries; ditches and other artificial drainage lines; domesticated animals and cultivated crops; man himself; and such other observable material features as may have been produced, either directly or indirectly, by human occupation and activities. Thus the existing landscape of any given date is a composite of the original, unmodified physical conditions of the area and the results of the interaction between them and man, as manifested by himself, his works, and their results.

Factors of the Natural Environment. These are the observable elements of landscape listed earlier: features such as topography and soils. Since they afford the initial attraction for settlement, and later serve as the basis for man's economic activities, it seems desirable to discuss the effects of each individually, and the collective effect ot all, briefly at present, with a more extended consideration deferred until later.

Space Relationships. These include relative location, size, and shape. The relative location of a region is good if it is easily accessible from other occupied areas; it is poor if it is accessible with difficulty. Excellence of relative location is, therefore, not measured in miles, but by accessibility, which affects both the obtaining of needed supplies and the marketing of surpluses. Thus the United Kingdom, located at the pole of the land hemisphere, is favored by relative location; the antipodes, Australia and New Zealand, are handicapped.

Countries vary greatly in size. Some are large; others are small; still others are of moderate areal extent. At one extreme is the Soviet Union, larger than some of the continents; at the other, a principality such as Monaco, smaller than many a large farm or tropical plantation, so small that its area is best expressed in acres. Too small a size is a disadvantage, for it minimizes the possibility of a desirable degree of self-sufficiency, in addition to imposing other limitations stated earlier, or to be considered later.

The shape of areas likewise varies greatly, either favoring or handicapping a region. Thus attenuation or elongation, like that of Chile, which has a north-south extent of 2500 but an average width of only 111 miles, produces conditions which are less favorable than those in a compact but otherwise comparable area.

Climatic Conditions. The climatic elements—temperatures, moisture conditions, and winds—are possibly the most important of all the factors of the natural environment. They are, indeed,

the only ones which can, and occasionally do, impose such limitations on man as to preclude the practicability of his permanent occupation of certain areas under present and known conditions. Thus only the wastes of snow and ice of the Arctic and Antarctic, limited areas of great elevation and low temperatures, and shifting desert sands are destitute of all permanent inhabitants.

Soils. If soils are both deep and fertile, and climate is favorable, man commonly avails himself of this opportunity to practice agriculture. In fact, areas with these favoring assets support some of the world's densest populations, such as those of the plains of the great rivers of China and India. By contrast, even where climatic conditions are favorable, if soils are shallow or unproductive, except as activities other than agriculture serve as the basis for support, population will be of only moderate density, and it may even be sparse.

Ground Water and Natural Drainage. Ground water, supplied by rainfall and stored underground, serves both to feed streams and to satisfy human needs. Therefore, where it is deficient in amount, man, particularly in the earlier stages of his advancement, finds the lack a great disadvantage.

Natural drainage may either impose a restriction or aid man in his attempts to use a given area as his home. If such drainage is poor, marshes and swamps may interfere with communication and efforts to use the land, this being particularly true during the earlier periods of history and among less advanced populations. These are but two of the many ways in which natural drainage functions to either increase or decrease initial areal opportunity; others will be discussed later.

Topographic Conditions. These are among the more obvious of the factors of the natural environment which affect the suitability of an area for supporting man. If slopes are steep, soils will be shallow, and conditions will be unfavorable. By contrast, if slopes are gentle, or the land surface is flat, soils will be deeper, and the probability that they will be productive is greater. That regions of slight relief, or without great surface irregularity, are the favored home of man is indicated by the present distribution of the world's population, the major portion of which is localized in plain areas.

Flora and Fauna. The plant and animal life of an area are both important in either denying or offering opportunity to man. If the plant life satisfies many human needs, this adds to desirability; if it meets few, areal attraction is decreased. The same is true for animal life. In the Americas, for example, none of the animals native to either supplied good beasts of burden. The dog was too small to be very effective; the llama of the Andean plateaus had a similar limitation. In North America, the bison, though large enough, did not lend itself to domestication, and other large animals suitable for use were lacking. This markedly handicapped the Indian populations.

Mineral Wealth. The presence of varied and valuable commercially exploitable deposits of minerals adds greatly to the desirability of any area. The absence of such deposits imposes a great handicap by forcing dependence on other regions for a supply of materials indispensable in these days of complex industrial development, though of much less significance at an earlier period of the world's history. The United States is very fortunate in this respect, being completely self-sufficient in a large number of the important minerals, and capable of supplying its own needs for several others in an emergency, when outside supplies from more valuable occurrences are cut off. This has stood us in good stead recently, though demands have now depleted some of these reserves so seriously that they will no longer meet our necessities.

Contact with the Sea. Those areas with extensive and highly indented coastlines enjoy intimate contact with the sea; others are accessible from the oceans only with difficulty, thereby being handicapped, for easy contact with the sea not only facilitates the flow of trade, but also extends an opportunity for securing a living to the land's population. This may be by fishing, the carrying of trade, or in other ways. The insular character of the British Isles, for example, by contrast with the continental location of the Soviet Union, explains at least in part the greater dependence of their population on trade, their accumulation of widely scattered holdings, and their foreign policy, particularly that of the past.

Effects of the Total Natural Environment. From the preceding general discussion of the individual factors of the natural environment, which will be considered later in much greater detail. it is apparent that each limits the range

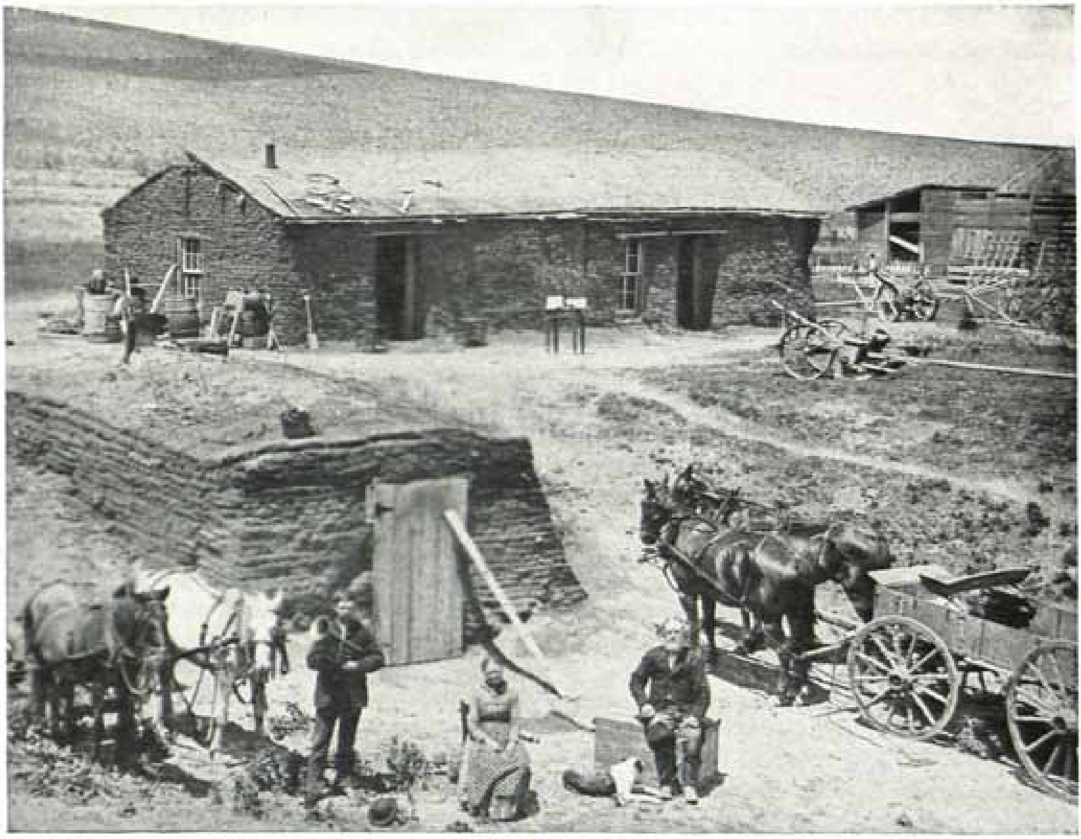

FIG. 27. Two types of Nebraska sod house near Clear Creek, Custer County. One is a dugout; the other is entirely above ground. The walls of such houses were made of strips of sod, laid with the joints broken, and with every third course laid crosswise to bind the others together. The roof was constructed by covering a framework of poles with prairie grass and then with sod. When means permitted, the roof was supported by rafters, to which wood sheathing and tar paper were applied. Then this was covered with sod with the grass side down, cracks being filled with clay. These houses were cool in summer and warm in winter, but they were poorly ventilated and they seldom lasted longer than six or seven years. They were also hard to keep clean for dirt dropped continually from the roof and walls and they leaked badly during rains, dripping water long after the rain was over. Sometimes the water-soaked roof became so heavy that the side walls, weakened by rain, could not support the weight and the building collapsed. (Courtesy of the Nebraska State Historical Society.)

of effective human choice materially. Therefore the sum total of their influence on man assumes great importance, for they affect his works, his economic activities, his social organization, and even his literature. Among primitive populations, the effects commonly extend to religious beliefs as well.

Effects of Environment on Man's Works. An example of the effect of environment on the works of man is afforded by the variation in house types from locality to locality. Wherever wood is abundant, it is a commonly used building material. This is true in Japan, the forested Scandinavian countries of northwestern Europe, and in much of European Russia. In our own country, it supplied the material for the log house with roof of hand-split shingles, favored by the pioneers of the forested East.

By contrast, where wood is scarce but stone is plentiful, as in Mediterranean areas, the latter is generally used for buildings. This is particularly true where sandstones and limestones, which break readily into rectangular blocks, are available. Thus there is a marked resemblance in house types in the lands which border the Mediterranean.

In the arid regions of the earth, where both wood and stone may be lacking, their place is commonly taken by clay, molded wet, then dried in the sun or baked by fire into brick. This was the material used for building the palaces and temples of ancient Babylon, and it is still used throughout much of northern Africa, southwestern Asia, and North China for the houses common in those areas, even though such buildings have a tendency to "melt" during torrential rains. In furnishing these houses, also, clay is often used, not only for making jars and similar utensils, but for other household equipment as well. In our own country, the adobe houses of the Southwest are built of sun-dried brick, much as are many of the houses in the drier parts of the Old World, and in the northern portion of the treeless Great Plains, the houses of the early settlers were commonly "soddies," such as those shown in Fig. 27.

Effects of Environment on Man's Economic Activities. Man makes his living in a variety of ways. Where the inhospitable character of the home area imposes too great limitations on possible economic activities on the land, he may even turn to the sea for support, as in Greenland, Labrador, and similarly handicapped regions. If the land offers any opportunity, however, even though slight, it is generally embraced, either as the basis for full-time occupation, or to supplement income derived from the sea. This oppor-

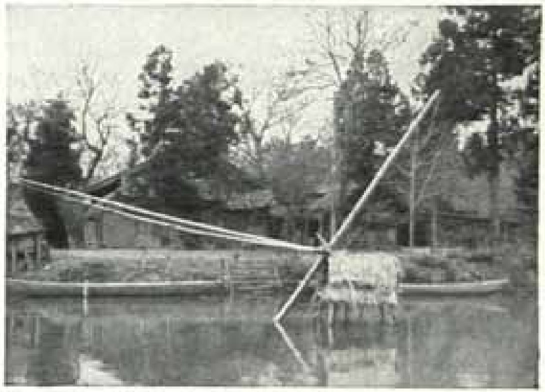

FIG. 28. Fishing, to supplement farm income, on the Echigo Plain, western Japan. The farmhouse in the background fronts on one of the distributaries or branches of the Shinano, in the delta of that river. The structure on posts in the foreground is a shelter for the fisherman, as well as a support for the net, which is tripped by means of the projecting pole. In this densely populated area of small farms, supplementary occupations such as fishing are necessary, even with the existing low standards of living.

FIG. 29. El Ued, an oasis in the Suf, Sahara Desert. The palm trees are planted in depressions dug to such depths that their roots can reach ground water. Since these depressions tend to fill with drifting sand, it is necessary to keep them cleared to prevent burial of the trees. In such an oasis, it is not necessary to water the trees, but other crops, principally vegetables, must be supplied with water drawn by hand or with crude sweeps from open wells. Land as such is valueless; only palm trees, planted with much labor, evidence wealth. In few areas is agriculture carried on so laboriously as in the oasis of El Ued. (Courtesy of Theodore Benzinger.)

FIG. 30. The large, pierced slab of stone at the right is the "stone money" of Yap. The women in the foreground, in their native dresses made from material obtained locally, are part of the harem of the wealthy chief of the island. Standing at the left is the Executive Officer of the mine sweeper *Bittern*. (Courtesy of W. H. Hobbs.)

tunity may range from grazing to agriculture; it may include mining; or it may even involve industrial development and dependence on trade. Which of these it is, either singly or in combination, will depend on environmental conditions in major part. If rainfall is limited, but sufficient to grow grass, grazing presents an obvious opportunity, and flocks and herds may serve as the basis for support of either a nomadic or a sedentary pastoral population. If rainfall is more abundant, other climatic conditions are favorable, topographic conditions do not prevent, and soils are fertile, agriculture may be the dominant economic activity of the population. If neither grazing nor agriculture is possible, but mineral wealth is present, mining may assume great importance in the economic life of an area, in some cases serving as one of the bases for the development of manufactures. Again, power developed by use of coal, or available energy supplied by streams, plus nearness to raw materials and markets, may likewise lead to the emphasis of industrial development as the basis for human support. Thus man's economic activities are predicated rather largely, though not entirely, on environmental opportunity.

Effects of Environment on Man's Economic and Social Organization. In established civilized communities, the wealth of the individual is measured in terms of tangible possessions such as land, buildings, animals, stores of commodities, or tokens which can be exchanged for these material expressions of accumulation resulting from initiative and thrift. Among many populations, and under certain environmental conditions, however, property, or the evidences of wealth, may not include all of the preceding list, and it may assume a different form. In very high latitudes, in the dense forests of the tropics, and in the oases among the dunes of the Suf, the land, except as improved by man, is of no value. Therefore land ownership as such is of no importance, and wealth is reckoned in other terms. Thus, among some populations of the Sahara, wealth may consist of palm trees, or the possession of a water supply; in other parts of the world, as among the Lapps, it may be reckoned in reindeer, which support the population. Again, "money" often assumes strange forms. Sometimes it is not even a medium of exchange, as on the island of Yap, where great circular slabs of stone, the celebrated "stone money" imported at the cost

of much effort from considerable distances, are ranged before the houses of their owners as evidence of economic position in the community.

Family organization among less advanced populations is likewise often influenced materially by environment. Thus, where dependence for a livelihood is on the chase, the successful hunter assumes leadership; other members of the family or group occupy subordinate positions. In other cases, the matriarch may be the source of family authority where the character of the regional occupation dictates this as advantageous. Within the family, the position of each age group likewise varies with the basis for support imposed by stage of development, environmental limitations, and other factors. Among primitive hunting populations, for example, maturity ensures a position of importance; youth one of dependence. The aged, since noncontributing and past the possibility of contribution, may even be considered a permanent liability of such importance as to result in their being allowed to die prematurely, or even in their being put to death. Further, where life is precarious at best, as a result of scant natural opportunity, communistic practices in some degree are not uncommon, families sharing at least in food supply. This is often advantageous at a low stage of development, where no provision for the future exists, so that the existing plenty of one family may shortly be replaced by actual want, if sharing of temporary advantage is not the practice.

With increasing density of population, even among relatively primitive populations, some social organization of units larger than the family is common. Exactly what form this will assume is affected by the environment of the area where the given population group lives and makes its living. In the case of a nomadic hunting population, for example, it may consist of small, roughly federated groups, united only in emergencies. The smaller units of such an organization are "democracies" of the hunters and warriors, with leadership chosen for skill in the chase and war, the federation being less effective in the everyday life than the control exercised within the smaller constituent groups. This is a logical social organization where natural opportunity and stage of development dictate the chase as the basis for support. Among dense sedentary agricultural populations, and in highly industrialized areas, this intimate and obvious relationship between the type of social organization and the environment is either obscured or it disappears completely.

Effects of Environment on Literature and Religion. When man, prior to his knowledge of conditions other than those of the homeland, translates his ideas into words, either spoken or written, he is limited in the form of expression by his experience, which is conditioned by environment. Therefore the inhabitants of continuously warm areas never describe snow, nor do the inhabitants of cold regions such as Greenland ever attempt to picture the high temperatures and luxuriant vegetation characteristic of many equatorial areas, for such phenomena are outside the range of their knowledge and experience. Thus the literature of a people is often influenced by the local environment. For example, the Old Testament abounds in figures of speech which indicate that the Hebrews lived in a relatively dry region, where rains were commonly torrential downpours, and where pasturage was both uncertain and none too good at any time because of soil moisture deficiency.

Not only is description of the present world influenced by the local environment but, among less advanced population groups, the hereafter as well must be envisioned in terms of everyday experience. Thus the life to come for the good on earth is pictured as supplying in full measure all in which the local environment may be lacking; that for the wicked, as an exaggeration of the undesirable characteristics of the home area. For example, the heaven of a nomadic hunting population is a region abounding in game, a "Happy Hunting Ground"; that of a nomadic pastoral population, one where water is abundant and pastures are continuously good. That of a primitive native population of cold areas is a warm region where winter never comes, the idea of a happy hereafter held by the Eskimo. By contrast, the heaven of the natives of equatorial Africa, where both temperatures and humidity are high and manual labor is very trying, is a place where work is unnecessary and a life of continuous ease a possibility. Conversely, the hells of these various populations lack the desirable characteristics visioned for the heavens. In all, however, the component elements of these pictures of the hereafter are based upon everyday experience, which is limited by environmental conditions of the home area.

FIG. 31. Holyrood stock farm, 3 miles from Lexington on the Harrodsburg Pike, Fayette County, Kentucky. Well-shaded pastures and fine stock are characteristic of the Inner Bluegrass region.

Environment and Early Man. Man must have had his origin where environmental conditions were such that he was able to cope with them successfully at a stage of his development when he had no knowledge of clothing or how to kindle a fire. At that time, his home must have been in regions without extremely cold winters, or at least such would be indicated by logical

FIG. 32. A typical farm home in Fayette County, Kentucky. Located on the Jackson Highway near its junction with Van Meter Pike. Fine homes, set in spacious lawns, are common in the Lexington area.

considerations. From such areas, he advanced slowly into colder and colder parts of the earth's surface, as increasing knowledge of how to meet these new conditions effectively came within the field of his information. Even today, however, cold winters are a deterrent to many population groups in the occupation of an area, and it is more than possible that the common fear of the northland is an inheritance from the more remote past, when man was a naked savage, without adequate protection from low temperatures, and without knowledge of how to secure such protection by his own efforts.

Environment and Savage Man. This same repressive effect of low temperatures still manifests itself, in somewhat modified degree, among less advanced populations, even among those actually inhabiting high latitudes. It is true that these groups have progressed sufficiently since the earliest days to make protection against low temperatures possible. Nevertheless, the great climatic limitations of such areas, plus lack of intercourse with other parts of the world, make necessary a type of existence very different from that which would be possible with a somewhat more advanced population group. Thus the food supply, shelters, clothing, utensils, and all other features of their material culture are definitely confined within a narrow range of selection, imposed by low temperatures.

Environment and the Pioneer. With pioneer occupation of the region west of the Appalachians in the United States, and in similar fashion elsewhere in the world at that time, the relative desirability of areas was determined largely by the extent to which they permitted a considerable degree of self-sufficiency. A region which afforded game and fish, timber for construction and fuel, springs or some other source of water supply, and a limited amount of level land with soils of fair fertility was considered at least as good, and often better, than one with more level land and productive soils, but lacking in building material, fuel, and a readily available supply of water for domestic use. Even though we today estimate the relative values of these two areas differently, it should be realized that, at an earlier date, and from the standpoint of the pioneer, the older evaluation was correct.

Environment and Civilized Man. As man has made progress, step by step, additional areas have become capable of effective use, and accompanying shifts of population and changes of population density have occurred. Today, few parts of the earth's land surface are incapable of supporting inhabitants. This results from the fact that civilized man can occupy any area if it offers a single asset that is able to serve as the basis for economic activity which will afford support. Even the wastes of snow and ice of the polar areas, particularly those of the north, over which routes of future air lines may pass, are attracting ever-increasing attention, and assuming greater value as possessions. Therefore, areas such as those of the high latitudes, formerly considered valueless, take on a new significance, in view of their effect on our national welfare and our planning for national security.

The Operation of Environment. The environment exerts no compulsion on either an individual or a population group, for it operates only by presenting and limiting opportunity, thus affecting the range of effective human choice. Thus two regions with similar natural assets may develop along different lines, or in differing degrees. However, in areas with unfavorable environmental conditions, development will always be limited, irrespective of human choice.

A Favorable Environment Permits Progress. A favorable environment is one in which the range of effective human choice is extensive. For example, an easily accessible area of sufficient size and compact shape, with gently rolling topography, deep and fertile soils, adequate natural drainage, and favorable climate would afford opportunity for varied and profitable agricultural production in sufficient volume to ensure marketing surpluses to advantage. If, to the foregoing environmental assets, commercially exploitable deposits of mineral wealth are added, mining becomes an additional possible occupation. If forest wealth in quantity and quality to permit commercial lumbering is also present, still another remunerative occupation becomes available. Such a concentration of environmental advantages establishes the basis for the many effective choices which make possible the varied activities characteristic of economic life in highly developed areas.

There are many examples of environmental settings in this country which present man with several choices of occupation, all profitable. This is one reason why the United States is the envy of the civilized world. It is regions such as these

FIG. 33. Typical Kentucky Mountain topography, Breathitt County. Farms are confined to the narrow valley floor, on either side of which the steep, forested slopes of the bordering "mountains" rise to heights of several hundred feet. These ridges, which are uninhabited, impose serious barriers to travel from valley to valley. Within any given valley, however, there is no isolation, for the road, bordered by small farms, follows the creek. In places, indeed, it is in the creek bed. Under such conditions, it is a very poor road.

that support considerable populations, for they are foci of attraction because of the promise they hold forth of a satisfactory livelihood to be obtained in a variety of ways.

An example of a focus of this type is afforded by the Kentucky Bluegrass region, to which settlers flocked shortly after the American Revolution, lured by reports of its desirability by Daniel Boone and others. There was a settlement at Harrodsburg as early as 1774, and by 1790, Lexington, the unofficial capital of the area, was a place of 834 persons. This was a considerable population at that early date, when there were few towns of any size in the United States. Even excluding towns, the rural population exceeded 50 persons to the square mile by the close of the century, and increase has been steady since that time. The early attractiveness of the area is evidenced by the rapidity with which it was settled, despite the danger of Indian attack and the difficulty of travel, both overland and by river. Today, after more than 150 years of occupation and development, the better parts of the Bluegrass, sometimes referred to as the "Heart of Kentucky," present prosperous agricultural landscapes surpassed in beauty in few if any parts of the United States. In these areas, acceptance of great environmental opportunity has resulted in progress, evident even to the casual observer.

A Poor Environment Causes Retardation. If, by contrast with conditions in the Bluegrass, relatively flat land is limited in extent and bordering slopes are steep, soils will in general be shallow, especially on the slopes. They may likewise be poor, even where topographically suitable for agricultural use, particularly if soil erosion is active, as is frequently the case on the slopes which margin the flatter land. In such an area, even though climate may be favorable, agricultural opportunity is limited by other environmental factors which eliminate the possibility of

more than a subsistence type of farming, without surpluses for marketing. Further, topography interferes with transportation. Hence roads will be either circuitous or handicapped by heavy grades, and most of them will be poor. These conditions tend to fasten isolation on the inhabitants, depriving them of the benefits of contact with the outside world. This leads to an undue satisfaction with mediocre and limited achievements, in the absence of a satisfactory basis for comparison. Therefore progress is arrested, and the area is commonly thought of as "backward." Cut off from the main stream of progress, which flows without undue interruption in the accessible areas outside, such an area becomes a "backwater," in which, as time goes on, submarginal elements of the population accumulate and multiply, for the more progressive members escape to seek a living elsewhere, in some region of greater natural opportunity, and no infusion of new blood from outside occurs because opportunity does not beckon in this region of limited environmental assets.

An example of an area of the type described in the preceding paragraph is afforded by the Kentucky Mountains, the highly dissected portion of the Allegheny Cumberland Plateau in eastern Kentucky. In general, the only remnants of the original plateau surface are the narrow ridge tops, the "mountains." Therefore the area consists of a maze of narrow valleys, trending in various directions, with the stream courses bordered by limited amounts of flat land.

This region was settled at the same time as the Bluegrass, and by the same population stock, many parties which started for the Bluegrass by overland routes through the Mountains splitting, some of the members electing the rough country of eastern Kentucky as a place to remain and establish a home. This decision is understandable from the point of view of the pioneer. The area afforded him opportunity: some level land and a favorable climate for a self-sufficing type of agriculture, with corn the favored crop; timber for construction of a log house and fuel; water supply from streams and numerous springs; and game and fish in abundance. But, with environmental opportunity limited in both amount and kind, and with large families the rule, the small amount of level land was soon occupied, and game disappeared under intensive hunting. Shortly, population became too dense to be supported without depression of standards of living. This led to malnutrition and deterioration of the population stock. Cut off from the outside by lack of effective means of communication, progress was very slow, or retardation occurred, so that, up to a relatively few years ago, the Kentucky mountaineers might be found living under much the same conditions as those common on the frontier shortly after the close of the American Revolution.

During recent years, it is true, conditions in many parts of eastern Kentucky have altered materially with construction of rail lines and exploitation of the mineral resources, particularly coal. Nevertheless, living conditions remain generally poor, and living standards are still low

FIG. 34. A typical Australian black. Since it is warm in the Australian Desert where the "blacks" live, he wears little clothing. Note the thick, but not protuberant lips, and the features, which are not those of the Negro. The scars on the chest were made at the age of puberty, at the ceremonies known to whites under the native generic term for initiatory rites, "bora". The exact pattern of the scars varies with the tribe, but in all cases they indicate the attainment of maturity. (Courtesy of Griffith Taylor.)

FIG. 35. Building a "gunyah" or shelter. This is constructed by covering a framework of poles with bark of the eucalyptus, several species of which make up much of the scrubby growth where the Australian blacks have their home. Such a structure can be erected in an hour, so that its abandonment, made necessary by the nomadic habits of life of the blacks, entails no great loss. (Courtesy of Griffith Taylor.)

in the more isolated areas, affording great contrasts with those of the Bluegrass, only a few miles away.

Repressive Environments and Retrogression. Wherever environmental conditions restrict man's choice too greatly, and impose too great a limitation on the opportunity offered within the range of the most effective choice, it is possible that the population will make no progress. In fact, indications of actual retrogression may be evident in such areas. The repressive environments which may produce such an effect fall into three classes: those which are too dry; those which are too wet; and those which are too cold.

Regions with such environments are normally occupied by very primitive populations. In all probability, they were formerly inhabitants of more promising areas, of which they were dispossessed by stronger population groups, for it is difficult to believe that any group would, without compulsion, choose these undesirable locations were others open to them. Some of the reactions of man to regions of this type have been considered previously. In the present discussion, the effects of the arid conditions of the great desert of central and western Australia will be used for illustration.

Topographically, and as regards soil conditions, much of the Australian desert is suitable for habitation and a high degree of development. However, rainfall is so small in amount that other advantages fail to offset the precipitation deficiency. At William Creek, on Lake Eyre, the average annual precipitation is only 5.4 inches, and, in much of the surrounding area, the normal rainfall is less than 5 inches. Lake Eyre itself is

usually only an expanse of dry, salt flat; only occasionally does it contain water. Further, the rainfall of the Australian desert is erratic in occurrence. Sometimes no rain falls for as much as two years or more, and then in torrential downpours. Therefore much of the water runs off without penetrating the soil, and, because of the high temperatures, sometimes as high as 115° F. in the shade, an additional large amount evaporates directly into the dry air, without benefit to life. Under such conditions, vegetation is sparse and animal life is limited.

The inhabitants of this area, so lacking in natural opportunity, are the Australian blacks, sometimes known as the "blackfellows" because of their dark copper, or chocolate-colored skins, though they are not Negroes. They are one of the most debased populations of the entire world. Forced to change location frequently with the disappearance of game in a given locality, they lead a migratory and precarious existence, within the limits of the tribal hunting grounds. Their shelters are crude and temporary, as shown in Fig. 35. Even with constant migration, only an inadequate food supply for the limited population, dependent on game, seeds, roots, grubs, and reptiles, is available. Cannibalism was a common practice in the past and probably still persists. The necessity for a continuing shift of location and struggle for any kind of food supply, no matter how poor, precludes the possibility of acquisition of many material possessions and leaves little leisure for development.

Mentally, the Australian blacks are children. They have no general terms such as tree, bird, or fish, but only a name for each plant and animal known to them. They have words for one, two, and three, but four is ordinarily "two-two." They have no recognizable religion and no idols, but possibly some vague idea of a hereafter. The existence of the blackfellows is, in fact, almost on the plane of that of the larger animals which furnish part of their food supply. So little progress have they made in the unfavorable environment of their home area that they still live as our ancestors must have existed in the very remote past, long before the period of written history.

Though the occurrence of actual retrogression may be difficult or even impossible to establish conclusively for a given population, its inevitability under sufficiently unfavorable conditions is undeniable, and such evidence as we have indicates that it occurs. Huntington, for example, notes the "persistence" of characteristics and the "passion for agriculture and herding" among the Ba-Kalahari, or the inhabitants of the margins of the Kalahari Desert, which would indicate retrogression of these people, driven from a better watered area and today living in a dry region where they are dependent on hunting for most of their food supply.

Effects of the Cultural Environment. The cultural environment is a composite of those features of the landscape reflecting man's activities. It includes such elements as cultivated fields, artificial drainage lines, buildings, transportation systems, and also man himself. These aspects, as well as those which represent a natural inheritance, will be considered later in more detail; for the present, discussion will be limited to stating some of their effects.

As has been indicated earlier, nature, unmodified by man, seldom if ever offers maximum opportunity. When man appears on the scene, however, he alters the environment in his attempts to obtain a living. Generally, though not always, this leads to a betterment of conditions. For example, land clearing and swamp drainage increase the area capable of agricultural production and generally permit support of additional numbers; road building and rail construction facilitate movement of goods and enhance desirability. Even the mere presence of man, especially if his numbers are considerable, modifies areal attraction and affects the kind and degree of opportunity, as has been stated in considerable detail in earlier chapters.

Therefore the relative desirability of areas is influenced, not only by natural inheritance alone, but by such inheritance as modified by man, his works, and himself. Often, indeed, areas of relatively low initial opportunity develop great attraction, subsequent to human modification, sometimes to the extent that present economic activities are best explained in terms of the cultural rather than the natural environment.

The possibility of producing such a desirable alteration of opportunity in areas of slight present attraction by the proper procedures is what makes *regional planning* so much preferable to the trial and error methods of the past, always assuming that the planning is by competent individuals, whose decisions will be based on economic rather than political considerations.

QUESTIONS AND EXERCISES

1. What are the two major divisions of the observable features of the landscape of a region occupied by man? What is the basis for the distinction between the two? What are some of the elements of each subdivision?
2. Place a globe with London at the top and note the location of Australia and New Zealand. Why are Australia and New Zealand said to have an antipodal location? What is the area of the Soviet Union in square miles? How large a fraction of the total land surface of the earth is this area? What is the area of Monaco? How does this area compare with that of farms in your home region?
3. Name and locate several areas of slight elevation and relief which support dense populations.
4. What beasts of burden did the native animal life of the Americas supply to Indian populations? Were they of great value? Why? What crops did the Americas contribute to European agriculture? Did their introduction affect European agriculture markedly, and, if so, how, where, and why? How did the introduction of the horse affect the life of the Plains Indians?
5. How does lack of self-sufficiency in minerals affect certain nations today? Give examples. What would the relationship of Japan to the sea indicate as to the probable importance of such contact? Is this importance realized in the economic life of the Japanese? In what way?
6. How are Japanese houses constructed? Why? How and why do they differ from those of Mediterranean areas? Those of deserts? Why was the log house the usual pioneer type in much of the eastern United States? The "soddy" that of the Great Plains?
7. Under what conditions does a population turn to the sea for most of its support? Name some areas where this occurs. Why is fishing often a supplementary occupation in many parts of eastern Asia?
8. Why does possession of "stone money" indicate wealth in Yap? Why does ownership of palm trees indicate the same in El Ued?
9. What will be the probable social organization of a nomadic hunting population? Why is sharing of food supply often advantageous among less advanced populations?
10. Find some figures of speech in the Old Testament which indicate that the Hebrews lived in a relatively dry area during Biblical times. Describe in some detail the hereafter of a hunting population such as the Indians. Contrast this with that of a nomadic pastoral population.
11. Why did man probably originate in an area without extremely cold winters? Why did the early American pioneer often prefer an area of varied resources to one of greater desirability for agricultural use? Give an illustration of this. Why has the airplane caused increased interest in polar possessions, particularly in the Arctic?
12. What is the rural population density of your home state? Compare this population density with that of the Bluegrass region in 1800. What are the major economic activities of the Bluegrass region of Kentucky today?
13. Under what environmental conditions may retardation occur? Why is the topography of the Kentucky Mountains so rough? Where is the level land located? Where are the roads of the Kentucky Mountains located? Why?
14. Report on the characteristics of the Kentucky mountaineers. How and in what way are these characteristics related to environmental conditions? What characteristics, other than those listed in your text, evidence retardation in the Kentucky Mountains?
15. What has caused deterioration of the population stock in the Kentucky Mountains? Why are the Kentucky mountaineers sometimes referred to as our "contemporary ancestors"?
16. Name the three types of repressive environment and give an example of each.
17. What is the approximate area of the Australian desert? What fraction of the area of the United States is this? What is the amount of rainfall in inches in the Australian desert? What is the rainfall in inches for the area where you live?
18. What is the probable cause which makes a population group live in an area with a repressive environment? Describe the life led by the Australian blacks. On what do they depend for food supply? Why are such populations of interest, even though their numbers are small?

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Chapter Seven

THE CHANGING ENVIRONMENT: NATURAL AGENCIES PRODUCING CHANGE

Environmental Change and the Agencies Producing Change. That the natural as well as the cultural environment alters continuously is a matter of common knowledge, for change during less than a human lifetime, especially in areas occupied by man, is generally sufficient to be detected by even the most superficial observer. Sometimes the change is slow; sometimes, with the occurrence of great natural catastrophes, it may be exceedingly rapid; at all times, however, it is in progress. Thus areal desirability is modified, for either the better or the worse, as the environment alters. The agencies producing changes fall into two groups: (1) natural phenomena such as earthquakes, volcanic eruptions, floods, droughts, destructive windstorms, fires set by lightning, competition of life forms, and others of less importance, some because of the great slowness with which they operate; and (2) man's activities. The latter are more important, though they commonly attract less popular attention, unless they have political implications or possibilities. In this chapter, only the first of these two groups of agencies will be considered in their effect on both the natural and cultural landscapes.

Earthquakes. An earthquake is a tremor or shaking of the earth's surface layers resulting from any shock strong enough to cause movement of the crustal strata. Most of these disturbances are minor and without appreciable detrimental effects, but when one results from crustal deformation and vertical or other displacement of the underlying rock layers along a fault plane, or a "line" of weakness, often many miles in length, considerable observable surface change may result. The same is true when the shock is caused by either subterranean movement of lava or a volcanic eruption of explosive character. Earthquakes of this latter type are frequent where volcanism is active, both before and during eruptions, though more limited in the areal extent of their effects and less effective in producing widespread destruction and change than those associated with crustal dislocation along important zones of faulting.

In view of the causes of earthquakes, it follows that they are most frequent where crustal movement is active, or where mountain uplift is occurring and volcanic activity is marked. Two such belts of active crustal movement encircle the globe at approximately right angles to one another. One girdles the Pacific; the other extends in an easterly-westerly direction through the West Indies, the Mediterranean, southern Asia, and the East Indies. Studies which have been made indicate that more than 90 per cent of all important earthquakes of record have occurred in these two belts, with somewhat more than half in the second of the two.

Some of the major shocks have caused great loss of life and enormous property damage. It is estimated, for example, that 60,000 persons perished in the Lisbon earthquake of November 1, 1775, mostly from drowning by the great wave which swept over the waterfront, where many had taken refuge to escape danger from falling buildings. Throughout the Mediterranean area, to the east of Lisbon, earthquakes are common, both with and without accompanying volcanic eruptions. Among the more important of these may be listed the Calabrian earthquakes of 1688, 1693, 1783, 1905, and 1908, in all involving a loss of more than 195,000 lives, together with an equally imposing amount of property damage. Similarly, violent shocks have been recorded in the circum-Pacific belt: in Alaska, western United

FIG. 36. The Hibernia Bank Building, wrecked by the San Francisco earthquake of April 18, 1906. This shock was caused by a displacement of from 3 to 20 feet along an important fault line or rift many miles in length, just west of San Francisco, where the shock was especially severe. Fires which broke out after the earthquake spread rapidly and completed destruction of the city, as the water supply was cut off by the breaking of the mains. This earthquake and the accompanying fire was one of the great natural disasters of our time in the United States. (Courtesy of the U. S. Geological Survey.)

States, western South America, and eastern Asia. In Japan, for example, the Tokyo earthquake of 1923 demolished much of Tokyo, particularly the eastern portion on the recent alluvium or river flats of the Sumida River, causing a loss of thousands of lives in the narrow streets, where people packed in the limited open spaces were showered with debris from falling buildings and burned to death by the fires which followed the earthquake.

Earthquakes may modify topography, as did the New Madrid earthquake of 1811-1812 in the Mississippi Valley, which produced depressions such as the one in which Reelfoot Lake in western Tennessee stands today. They may also be accompanied by changes in coastlines, through either elevation or depression of the land surface and the ocean floor. The principal damage and change in environmental conditions result, however, from destruction of the works of man and loss of life. Though spectacular and attracting much attention, the total alteration of the natural environment by any single earthquake, or within a human lifetime, is normally not great, except locally, and even in these limited areas important permanent change seldom occurs. Over periods of geological time, however, the cumulative effects of crustal movement are marked.

Volcanic Eruptions. Whenever lava is extruded, either quietly or explosively, commonly by the expansion of steam or other gases contained in the melted rock, a volcanic eruption occurs. This will be relatively quiet, though terrifying, if the lava is thin and the pent up gases escape without too much difficulty; explosive in character if the gases accumulate until the pressure is sufficient to force out thick or partially solidified rock material from the crater. Such ejected material, either liquid or solid, gradually builds up a cone or mountain around the orifice

through which the lava escapes. If the lava flows readily, the cone will have relatively gentle slopes, like those of the Hawaiian volcanoes; if the eruption is explosive, the fragmented material will form a cone with steeper slopes, similar to those characteristic of many of the Italian and Japanese volcanoes. Since individual volcanoes may erupt differently at various times, the shapes of the cones reflect that fact, many being intermediate in form.

Lava flows vary greatly in extent. Many cover only a limited area, but some of the larger ones in Hawaii attain a length of as much as 40 miles, and a width of from 2 to 3 miles. These flows obliterate everything in their paths, destroying all life and the works of man, converting a previously productive occupied area into one of utter desolation and altered topography. When the eruption is explosive in character, it is even more terrifying and destructive. The lava, ejected high into the air, is fragmented. Some of the material is blown into very small particles which settle over the countryside as hot volcanic ash. In combination with the rains which frequently occur at times of volcanic eruptions, the ash may form a hot mud which flows down the slopes, engulfing all in its path. Such a mud flow, since solidified, entombed Herculaneum in 79 A.D., at the time of the eruption of Vesuvius. If the fragmentation is not quite so complete, a rain of rock fragments of variable but larger size falls. In addition to solid material, a blast of highly heated and often poisonous gases, such as sulphur dioxide, in addition to steam, may rush down the slopes of the volcano to destroy all life in its path. Such was the fate which overtook St. Pierre, on the island of Martinique, when Mont Pelé erupted on May 8, 1902. It is estimated that this blast, with a temperature of 1400-1500° F., traveled 3 miles in 2 minutes, a velocity of 90 miles an hour, overthrowing buildings and searing everything in its path. Then ash descended to bury the city.

FIG. 37. Destruction of Hoopulua, Hawaii, April 18, 1926. The advancing lava has buried the village completely, and along the front of the flow where it has reached the sea, great clouds of steam are rising. Spectators in the foreground are watching the spectacle from a safe distance. (Courtesy of T. A. Jaggar.)

Other explosive eruptions of similarly destructive character are known, that of the eruption of Krakatoa, in the Strait of Sunda between Sumatra and Java, in 1883, being outstanding. The sound of the explosion was reported in Australia, 2000 miles distant; great waves rose 100 feet in height on neighboring shores; ash darkened the skies for a distance of 150 miles. Had this eruption occurred in a more highly developed and densely populated area, the loss of life would have been appalling; as it was, 36,000 persons were killed on the island and adjacent coasts.

The belts of marked volcanic activity coincide with those where earthquakes, often associated with volcanic eruptions, are frequent. Thus one, sometimes called the "ring of fire," encircles the Pacific Ocean; a second extends eastward from the Mediterranean through southern Asia and the East Indies into the West Indies.

Volcanic eruptions are not only terrifying but enormously destructive, and productive of great changes in the environment. This is true not only for eruptions as we know them today but even more so for the great lava flows, of prehistoric though recent geological time, which issued from fissures many miles in length, burying everything beneath a mass of lava hundreds of feet in thickness. Such was the origin of the great lava plateaus of eastern Washington and adjacent areas in Oregon, Idaho, and northern California. From the disintegration of these lavas have originated the fertile soils of the wheat-growing areas of these states. Other flows of like character are known in northeastern Ireland, portions of Scotland, and the Deccan of India, the extent of this last flow rivaling that of the Columbia plateaus.

Floods. Floods occur when water levels rise rapidly along a shoreline, at which time land, ordinarily exposed, may be inundated. Thus normal river floods are caused by an excessively rapid runoff which the river channel cannot accommodate, with the result that any bordering, low-lying areas may be covered by the excess water. This abnormal runoff may result from either prolonged or heavy rains, or from too rapid melting of accumulated snow cover, or even from a single torrential downpour or cloudburst. In the case of river floods, therefore, the rise may be either sudden or gradual, sometimes involving a period weeks in length, but in either case the crest of the flood will be considerably above the normal river level.

Many destructive floods have occurred in the United States, particularly those resulting from the overflow of our great rivers, such as those of the Mississippi in 1927 and the Ohio in 1937. It should be remembered, however, that these irregularly recurring phenomena are not recent developments in river behavior, but that they have always been associated with rivers, sometimes beneficently, as in the case of the Nile in Egypt. In fact, it is probable that the floods of recent years have been surpassed as regards both the amount of stream rise and the extent of the area flooded many times during the prehistoric past.

In areas with poor natural drainage, where rivers have few and widely spaced tributaries, and numerous marshes, swamps, and lakes serve to store surplus water and feed it into the streams gradually, runoff is so regulated that stream fluctuations are inconsiderable and floods, properly speaking, do not occur. Again, in the case of rivers which flow in narrow, steepsided valleys, a rise of water in the normal channel does not cause flooding of important areas. Only where a river is bordered by wide belts of alluvium, extensive flat areas only slightly above normal stream stages, is it possible for the overflowed area to be extensive.

In such cases, the effects of floods may be very important. During the rise of the water in flood stages, the stream erodes or wears away its banks and makes minor changes in its channel; or in extreme cases, as in the Hwang Ho in China, shifts its course for many miles. In the event that the stream constitutes the boundary between political subdivisions, either major or minor, such shifts may cause boundary disputes, some of which have been carried into the courts for settlement.

During subsidence stages of a flood, stream velocity decreases and deposit of sediment or alluvium occurs. When this deposition is on the stream bottom, it may interfere with navigation, as well as with other uses of the river; when it occurs on the flat land bordering the stream course, it aggrades or builds up the plain. Inasmuch as most of the deposit and the bulk of the coarse sediment is dropped on or close to the river banks, this results in the formation of a low embankment or natural levee, the highest portion of the overflowed plain, near the river. Thus floods are responsible for some of the topographic fea-

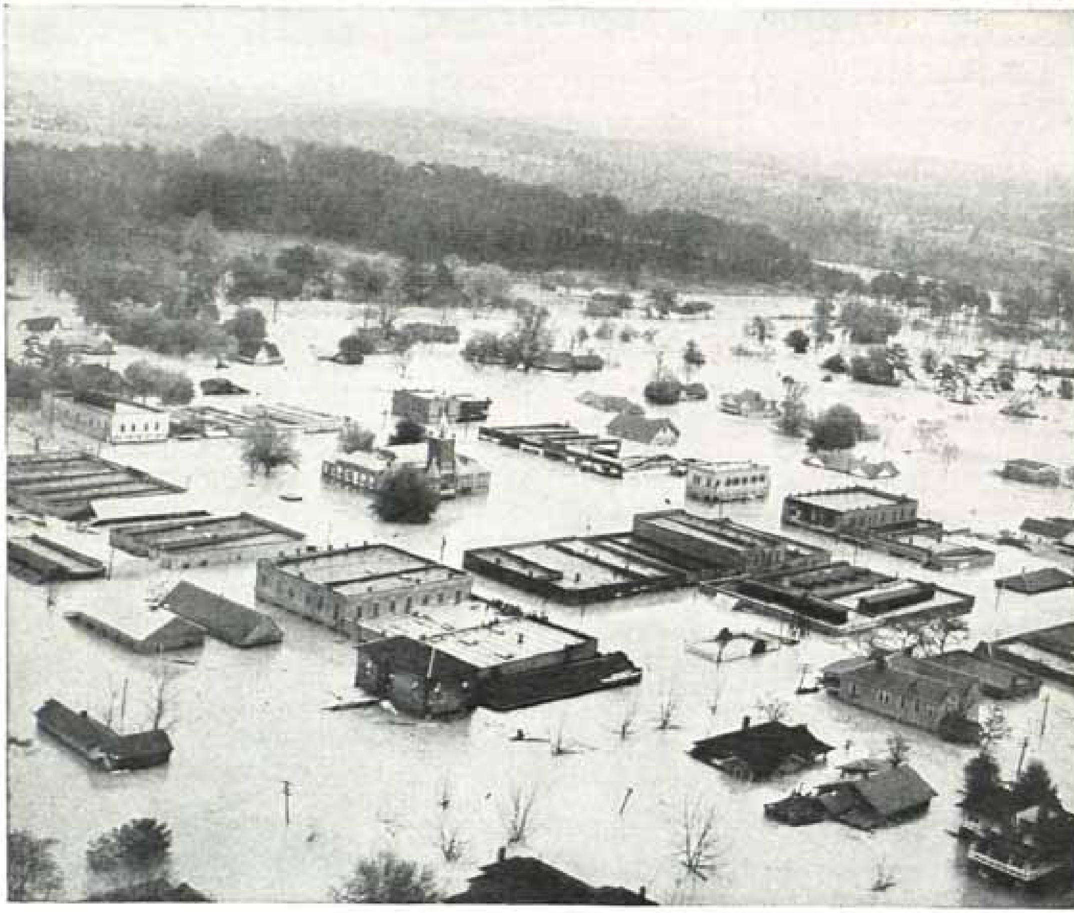

FIG. 38. Flood stage of the Pea River, a tributary of the Choctawhatchee, on the coastal plain of southeastern Alabama at Elba, March 15, 1929. In this area, runoff after heavy or prolonged rains is very rapid. In the background, the river is confined between higher land and the rise is confined to the normal channel but, at Elba, the unprotected flat land on which the town is located is subject to overflow at such abnormally high river stages. (Courtesy of the U. S. Weather Bureau.)

tures and the resulting drainage of the flooded areas.

Droughts. Droughts or excessively dry periods, which occur when precipitation drops to or below 75 per cent of the average, are infrequent and seldom of great length in well-watered regions, but west of the 100th meridian in the United States in the Great Plains Region they are so common and often so severe that they limit opportunity seriously and cause important changes in the environment. On the western range, the grasslands east of the Rockies, for example, there were from 1 to a maximum of 4 to 5 drought years out of every 10 during the 35-year period ending in 1933. These droughts were so detrimental in their effects that there was a great exodus of population from the drier part of the region, the so-called "Dust Bowl." This movement not only depopulated the dry area, but it also had important secondary effects far from the original home of the migrants, particularly in California.

These drier areas, where droughts are so frequent, originally had a native vegetation cover of short grasses of various species and supported enormous numbers of grazing animals, particularly bison or "buffalo." Later, with the advent of white settlement, these were displaced by vast herds of cattle. With subsequent agricultural invasion early in the present century, the sod was

FIG. 39. The effects of several years of drought on a farm in Cimarron County, in northwestern Oklahoma, the west end of the "handle" of that state, in 1939. Though the house was still occupied at that date, it and all other buildings have since been wrecked to prevent their use by squatters and future attempts at agriculture during favorable years. Eventually, this man-made waste will grass over and once more permit grazing of livestock. This is the use to which the area is best adapted, considering the limitations imposed by the climatic elements of the environment. (Courtesy of the U. S. Soil Conservation Service.)

destroyed and crops were planted. This disturbance of the balance of nature produced no serious adverse effects while precipitation was above normal in amount, but during the drought years of the early 1930's the soil dried out and strong winds caused it to drift. In extreme cases, the soil was removed completely from limited areas; in many others, it was damaged irreparably. Everywhere in such dry areas grass reestablishes itself with great difficulty, so that it will require many years to restore them to something approximating their former desirability. In such areas, therefore, drought, supplemented by man's activities, altered these dry grasslands in the direction of lesser desirability.

Windstorms. Windstorms competent to produce damage and change of importance are of two types: (1) the highly destructive, but fortunately local storms known as "tornadoes"; and (2) the much more extensive and more important disturbances, tropical cyclones, known as "hurricanes" in the Atlantic and "typhoons" in the Pacific.

Tornadoes occur during hot, sultry weather and are particularly prevalent in the Mississippi Valley. The exact date of greatest frequency varies with latitude: from early spring in the extreme south to midsummer and even later farther north. The greatest number normally occur in May.

Fortunately, the path of a tornado, along which wind velocities may reach 200 miles or more an hour, is very narrow and, generally trending in an easterly-westerly direction, is only a few miles in length. This path, however, is one of great destruction. If it passes through a forest, a clean swath with sharp, clearly defined boundaries is cut through the standing timber. Within this narrow strip, where maximum damage occurs, trees are twisted off as though they had been grasped by a giant hand; houses are demolished by the force of the wind or "exploded" by air pressure from within, as the partial vacuum of the vortex of the storm passes.

When the path of a tornado traverses a thickly settled area, loss of life may be considerable and property damage great. During the Lorain, Ohio, storm of June 28, 1924, for example, 75 persons were killed, many more were injured, and material losses probably exceeded $11,000,000. This amount is equal to the total normal annual loss for tornadoes for the entire country. Similarly,

FIG. 40. A tornado-cloud and funnel at Hardtner, Kansas, June 22, 1939. The tornado presents much the appearance of a gigantic dust whirl, the funnel which is characteristic of all such storms being the vortex toward which the winds blow. Tornadoes ordinarily travel in an easterly direction, with important damage confined to the narrow path described by the tip of the funnel as it travels across the land surface. (Courtesy of the U. S. Weather Bureau.)

100 persons were injured, though there was no loss of life, in the Cleveland, Ohio, tornado of April 27, 1943, which caused great destruction along its 300-foot wide path, 14 miles in length, through built-up portions of the city.

Hurricanes, though affecting the United States only along the Gulf and Atlantic coasts, and there with relative infrequency, are much more destructive than tornadoes because they are less localized in their effects. In the Caribbean and off southeastern Asia, however, such storms occur so regularly that they are accepted as a matter of course. Only when one departs from its normal path and ravages the coasts of the United States does it attract much attention in this country.

In these storms, winds reach a velocity of 125 miles or more an hour. This is sufficient to demolish all except the most substantially constructed buildings. It has been estimated that, if the energy of such a storm could be harnessed, enough power would be developed to meet the needs of the entire world for several years. Such an enormous amount of energy is obviously capable of producing great destruction. Part of the damage is produced only indirectly by the wind, for it is caused by "floods," or the piling up of water on low-lying shores and flooding of the coasts. Accompanying rainfall is also usually very heavy. This causes floods in the rivers; destroys roads, irrigation works, and railroads; and produces serious soil erosion, even on gentle slopes.

The most destructive hurricanes to affect the coasts of this country within recent years have been the Galveston disaster of September 1900, accompanied by a loss of 6000 lives, largely by flooding of the sand bar on which Galveston is located; the Miami hurricane of September 1926; and the New England hurricane of September 1938. In this last storm, as in the case of the Galveston flood, most of the loss of life occurred on low-lying, inundated shores. Even downtown Providence, Rhode Island, was submerged. Direct damage by the wind, which reached velocities of 90 to 95 miles an hour, was likewise great. Giant elms which afforded the major attraction of the streets and commons of many New England towns were uprooted or snapped off, destroying this beauty. A very large part of southern New England's trees were lost in this manner. Forests were converted into tangles of down timber which, unless salvaged, were a total loss, as well as an enormous fire hazard. The total property loss is estimated to have been $350,000,000. In the entire history of this country, only one other natural disaster, the San Francisco earthquake, produced a comparable amount of damage. The fact that this storm did not strike

FIG. 41. Tornado damage at Murphysboro, southern Illinois, March 18, 1925. Buildings in the foreground, in the path of the tornado, have been leveled; in the extreme background, to one side of the tornado path, little damage is evident. (Courtesy of the U. S. Weather Bureau.)

New York City was fortunate. It has been predicted that, if a severe hurricane should strike that city at flood or high tide, and at a fairly high water stage of the Hudson River, the resultant inundation would drown thousands as the water poured into the subways, quite apart from loss of life from other causes. Fortunately, the possibility of such a combination of conditions is slight. However, the New York area is not free from danger of such storms. The hurricane of September, 1944, for example, though less severe than that of 1938, caused a loss of 27 lives and property damage estimated at $50,000,000, in northern New Jersey, Long Island, and adjacent areas, including New York City, with the loss particularly heavy in Atlantic City.

Though we hear less of them, the typhoons of the Orient are even more disastrous than our hurricanes, because they affect areas with extremely dense populations, both on the continent and on the bordering islands as far north as southern Japan. On the small low-lying islands in the South Pacific, often only a few feet above normal sea level, great waves may drown their entire areas, destroying practically all life and much property.

One of these storms, accompanied by 12 inches of rain, which flattened crops and produced floods in the rivers, occurred near Calcutta, India, in October, 1942. Winds were so strong that they caused waves 15 feet in height to pile up water which inundated the shores along 40 miles of coastline. In all, 11,000 persons lost their lives, 10,000 by drowning; and 200,000 more were made homeless in the 1,000 square miles of territory affected by the storm. Such losses of life and property are typical in densely populated Oriental areas at times of typhoons.

Fires. Long before man knew how to kindle a fire, in fact before his advent on earth, fires of

FIG. 42. A Worcester, Massachusetts, street, after the New England hurricane of September, 1938. In addition to damage to buildings, giant elms were uprooted or broken off, thus destroying the beauty of the formerly well-shaded streets. This hurricane was one of the great natural disasters to occur in this country during the past 100 years. (Photo by J. W. Nystrom, Courtesy of R. M. Brown.)

natural origin must have ravaged extensive areas. The big trees of California and the spruce of Colorado bear scars in their hearts, some dating back as far as 245 A.D., mute testimony to the existence of forest fires long before the discovery of America, and many others which have left no such record must have occurred in the still more remote past. Even today, these fires set by lightning are much more numerous and important than is commonly supposed, for they comprise between 7 and 8 per cent, and in the mountainous regions of the western United States, as high as 50 per cent of all forest fires. Such fires cannot be prevented, only controlled when once started; to prevent those of other origins an intensive campaign has been carried on to make the general public conscious of the fire hazard in our forests during the dry season.

Fires set by lightning are equally as disastrous as those resulting from other causes and often much harder to bring under control, for they may start in inaccessible areas, far off any beaten trail. When they rage during a protracted period of dry weather and low relative humidity, they may devastate many square miles of timber, converting an attractive forest wilderness into a waste of blackened stubs and bare rock, in addition to taking a toll of life, both wild and human, and causing enormous economic loss.

Plants and Animals. Each species of plant and animal life living under natural conditions must engage in a continuous struggle with other forms of animate existence, from which only the fit elements survive. Grazing animals, for example, can live only at the expense of plants, each species depending on certain elements of the native

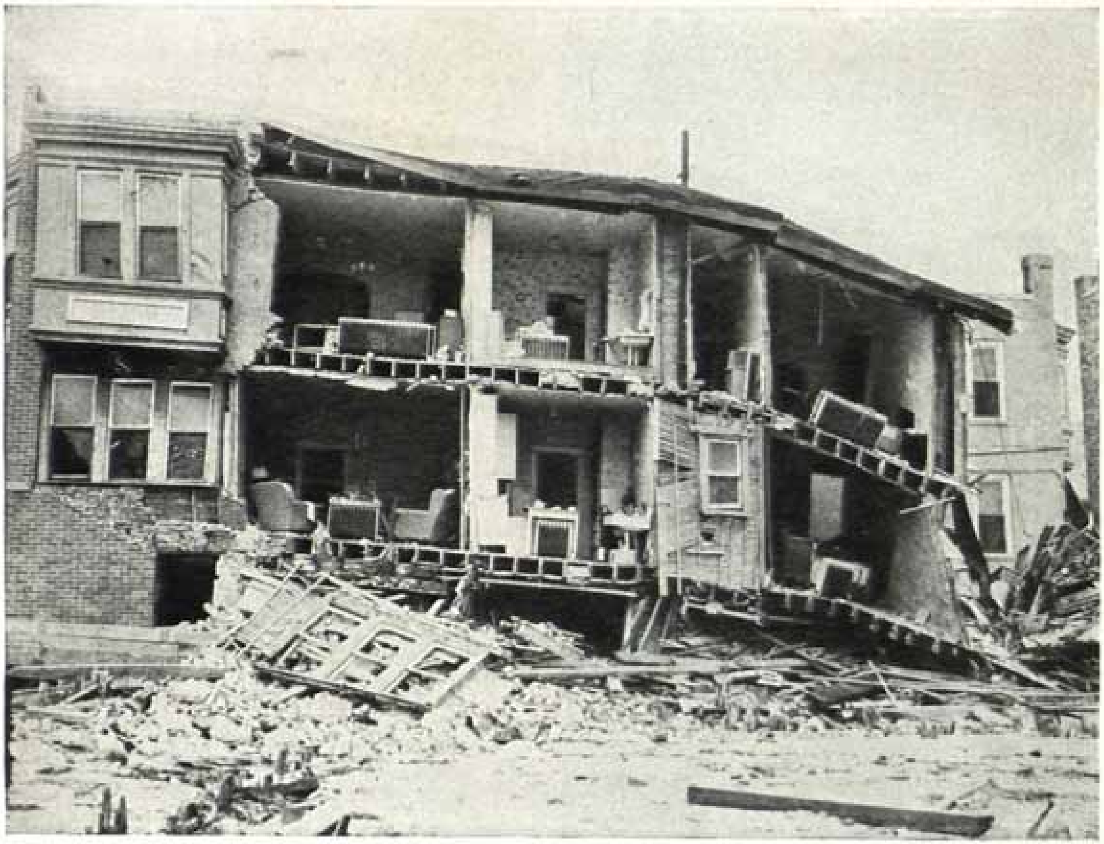

FIG. 43. Damage by the hurricane of September 14, 1944. On Seaside Avenue, Atlantic City, New Jersey. Part of the destruction may have been produced directly by the wind, but most of it resulted from water piled up on the low-lying shores which flooded the streets and wrecked the houses. (Courtesy of the U. S. Weather Bureau.)

vegetation for food supply. Thus these kinds of plants are kept in check, but eventually a balance is attained between the plants, the herbivorous animals dependent on them, and the carnivora which prey on other animal life. So long as conditions remain static, this adjustment between life forms of the natural environment is maintained, but when disturbed, as it is ceaselessly under natural conditions, a chain of events is set in motion which operates until a temporary balance once more exists.

Not only do animals which live on the surface and feed on surface vegetation and other forms of life alter the natural environment, but the same is true for the burrowing animals which spend much of their life underground. The most notable of these in intermediate latitudes is the earthworm, the results of whose work may be observed as irregularities on all lawns beneath the surface of which he lives in any considerable numbers. In his burrowing, he passes material through his body, thus altering it; and he likewise brings material from below to the surface, where it is incorporated in the mixture of organic and mineral matter which constitutes the soil. In fertile garden soil, where earthworms exist in great numbers, their work is very important. Not only do their activities affect the soil directly, but their burrows afford entrance for water, thus increasing both the rapidity and depth of chemical weathering. In the tropics, the ant occupies a position analagous to that of the earthworm in the higher latitudes in producing change in the soil.

The past has witnessed many alterations in the floral and faunal components of the natural

FIG. 44. After the Blackwater fire in the Shoshone National Forest, northwestern Wyoming, August, 1937. This fire started when an alpine fir was struck by lightning on August 18, 1937. In all, 1254 acres or nearly 2 square miles of timber were destroyed before the fire was brought under control and fifteen fire fighters, trapped in Rock Gulch above, lost their lives. Their water cans and other equipment can be seen in the foreground. (Courtesy of the U. S. Forest Service.)

environment of any given region, together with accompanying changes in other regional aspects, for the flora and fauna of any region at a given date are the end product of a ceaseless struggle of life, plant and animal, for a place in the sun. Since the arrival of man on the scene, this change has occurred at a greatly accelerated rate. Introduced species of both plants and animals have many times crowded out former important elements of the native flora and fauna to the extent that conditions today are markedly different from those of an earlier period.

Other Agencies Producing Change. In the preceding discussion of the effects of natural agencies in causing environmental change, only those which produce readily observable alteration within relatively short periods of time have been considered. However, it should be realized that others as well, working over longer periods of time, are of great importance. Among these may be mentioned the agencies of weathering, which cause the solid rocks to crumble; those of erosion: wind, water, ice, and others, which wear away the land surface and modify the topography; and climatic changes, which over long periods of time cause great alteration in the landscape. Further, in this chapter, only natural agencies have been discussed, except incidentally; the results of human activities will be considered in chapters which follow. However, it is obvious that change is the rule in the environment of any area, and that we thus live in a continuously evolving world.

Since both the natural and cultural environments are subject to continuous changes which alter opportunity, both actual and relative, all realistic and effective areal planning must be based on both present conditions and future possibilities in order to ensure sufficient flexibility to permit of gradual but considerable change over relatively short periods of time without entailing the probability of substantial loss.

QUESTIONS AND EXERCISES

1. What changes have occurred in the environment of your home state during the past century? Have they been for the better or the worse? In what respects?
2. What natural agencies producing environmental change operate too slowly to be materially effective during a human lifetime?
3. What are the two causes of earthquakes? Which type produces more widespread environmental change? Locate the two great belts of earthquake activity. Report on some of the great earthquakes of historic times, including those of the United States. What environmental changes have they produced?

4. What causes a volcanic eruption? State the two types of eruption and the effects of the type on the shape of the volcanic cone. What is the relation of the earthquake belts to those of great volcanic activity? To what extent and in what ways do volcanic eruptions modify the natural environment?
5. What was the origin of the lava plateaus of the Pacific Northwest? How did the eruptions which produced these plateaus differ from those of the present day? Of what economic significance are these lava flows in the areas of their occurrence?
6. What are the causes of river floods? Will the rise of great rivers be rapid or slow? Why? What are some of the detrimental effects of river floods? Are any of the effects ever beneficial, and if so, in what respect? In what parts of the United States are river floods unimportant? Why?
7. During what stage of a river flood does deposition of sediment occur? Why? What is a natural levee? Where is it located and how is it formed? Report on the former courses of the Hwang Ho. Where does it empty into the ocean at present?
8. Why are trees "twisted off" by a tornado? Why will air pressure "explode" houses in the vortex of a tornado? What is the wind velocity associated with tornadoes? With hurricanes and typhoons?
9. Where are hurricanes and typhoons particularly prevalent? How do they produce damage to property and loss of life? Why are the typhoons of the Pacific particularly destructive and accompanied by great loss of life in many instances? Why so destructive on the low-lying islands of the Pacific? Which was the most disastrous hurricane of those which have affected the United States? Describe the damage it produced.
10. Why are forest fires set by lightning often very difficult to bring under control? In what part of the United States are such fires especially important? Why? What environmental changes do they produce?
11. Report on the work of the earthworm in intermediate latitudes, and that of the ant in the tropics, in modifying the natural environment.
12. Explain how life exists only as the result of a continuous struggle, and why permanent balance is never attained. How does this affect regional planning? Why is it proper to speak of present environmental conditions as an "end product"?

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The two chapters recommended for reading are concerned with crustal movement and volcanoes. The treatment of these two topics is clear and adequate.

Chapter Eight

THE CHANGING ENVIRONMENT: HUMAN AGENCIES PRODUCING CHANGE— DEFORESTATION, FIRES, AND DRAINAGE

Man and Environment. The spread of man is not prevented, but only hampered, by climatic and other environmental barriers which restrict the natural range of plants and animals. Therefore his activities and their possibilities for producing change extend to practically all parts of the land surface of the earth. Further, he cannot occupy any area, no matter what his method of obtaining a livelihood may be, without altering it. Even the most primitive of hunting or pastoral populations modify the environment by destroying, either partly or completely, certain elements of the fauna and flora. This upsets a balance achieved over a long period of time and sets in motion forces over which man has no control.

As man's economic activities increase in number and complexity, their effect becomes ever more pronounced, and the landscape is altered even more extensively. Unfortunately, not only does man modify any area he occupies, but he frequently modifies it in the direction of lesser desirability and therefore to his detriment. In certain portions of the Great Plains of the United States, for example, attempted use of the land for agriculture, where natural conditions were favorable for grazing but not for the production of crops, resulted in the destruction of thousands of square miles of good range but not in the establishment of remunerative farming. Of such regions, it is said, and correctly, that "the desert is on the march." In this case, the desert is man made; its advance into contiguous areas still in attempted agricultural use is the result of man's activities. Human activities therefore affect the natural as well as the cultural environment.

The principal means by which man causes change in the physical environment and accompanying alteration of the cultural landscape are as follows: (1) deforestation, (2) fires, (3) artificial drainage, (4) grazing, (5) extractive industries such as mining, (6) irrigation, and (7) normal agriculture. The first three of these agencies will be considered in this chapter; the others, in the two which follow.

Deforestation. As a result of cutting and destruction by other agencies, our original forest cover of nearly 900,000,000 acres has been decreased to approximately two-thirds its former extent, with the bulk of the loss in the eastern half of the country. Of the existing remnant, only one-third has a stand of saw timber, and much of that is inferior second growth. Today our only remaining virgin stands in the East are confined to inaccessible localities. In many parts of the East, indeed, all the remaining timber is in farm woodland. Though the forests of the South still contain much merchantable timber, it is only on the Pacific coast that depletion is not serious. Even there, much that remains is not commercially exploitable because of inaccessibility; all is far from the principal markets; and cutting proceeds at a rapid rate. This has been particularly true during the past few years. In fact, the demands imposed by war have been so heavy that certain types of timber will not be available in the future in sufficient quantity to satisfy peacetime demands.

The virgin forests, which have been depleted so recklessly and to the detriment of the country as a whole, included a large number of useful species, probably surpassed in no equal area or country in the world. Under such conditions, it is

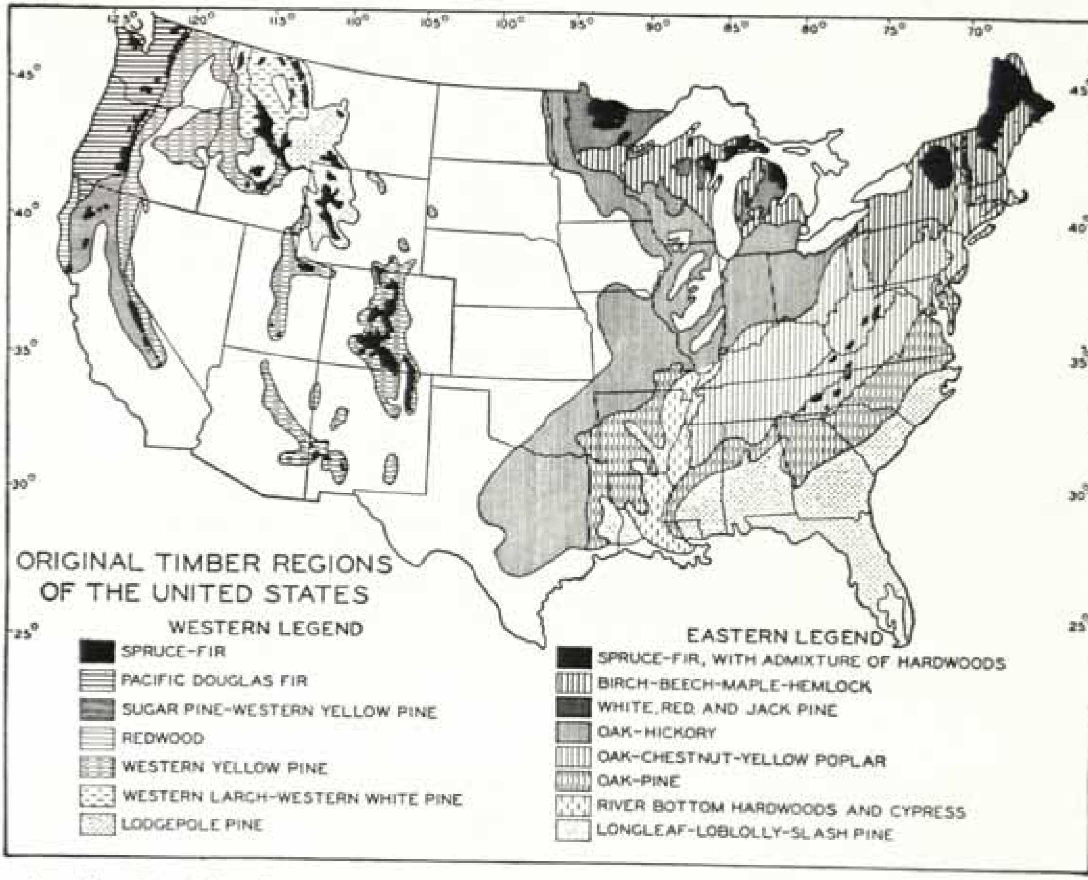


FIG. 45. Original timber regions of the United States, of which the eastern forests formed 83 per cent, and the western, 17 per cent of the total. Though the East still has 75 per cent of the total forest land, most of the remaining saw timber is in the West. (Courtesy of the U. S. Forest Service.)

not remarkable that our per capita consumption of wood has always been greater than that of other countries. Even today, though only a remnant of our forest inheritance remains, our resource is still envied by the world.

The early destruction of the forest in our predominantly agricultural areas east of the Mississippi River resulted in major part from clearing for agricultural use. The forest was regarded only as an obstacle to bringing the land into production, not as an asset, and it was destroyed without attempt to use or market any considerable part of the timber. Valuable woods were so abundant that in some sections black walnut was often used for fence rails, and for building the log houses of the pioneers. Only in portions of the South and of the Lake States, and today on the Pacific coast, has commercial lumbering always been the effective factor in forest removal, though for several decades cutting has everywhere been confined largely to an attempt to satisfy the demand for lumber and other forest products.

The earlier popular belief that destruction of the forest afforded no cause for alarm was based on several erroneous assumptions. One was that the supply of timber was inexhaustible. Another was that, with removal of the forest, the cutover land would pass into more profitable agricultural use. Though time and experience have proved conclusively that this is not always the case, the belief expressed by the statement, "We have gotten out of the forest and we do not propose to return," voices a point of view and a belief which still persists and finds expression all too frequently in many recently cutover areas.

FIG. 46. A virgin stand of white pine on the Arrowhead Trail in Cook County, northeastern Minnesota, in 1938. Today, all the larger trees have been cut.

FIG. 47. A virgin stand of hardwoods in North Carolina. Preserved by inaccessibility. (Courtesy of the U. S. Forest Service.)

Among other factors which contributed to rapid depletion of our forest resource was the fact that low prices for valuable timber stimulated consumption, which accelerated production and encouraged waste in both lumbering operations and use of lumber. Too rapid cutting was also forced in many areas by confiscatory taxation of privately held land, which compelled marketing of the timber as the only alternative to total loss. With partial exhaustion of our forest resource has come the realization that we have squandered a considerable part of our patrimony and altered the environment to our detriment. This is brought home by the increasing cost of lumber, use of inferior woods, decreases in sizes of stock dimensions in lumber, and the numerous substitutes which find a ready market today.

Destruction of the forest has effects which are in the aggregate probably more serious than higher prices and a shortage of lumber and other forest products. With exhaustion of saw timber or pulpwood supply, the basis for support of entire communities disappears; tax delinquency increases; political units become bankrupt and a liability to the state in which they are located. In certain counties of the cutover area of northern

FIG. 48. Cutover land in Menominee County in the Upper Peninsula of Michigan, in the process of being prepared for agricultural use. A discouraging undertaking rendered doubly so by the fact that, even after clearing, the land is of low agricultural desirability.

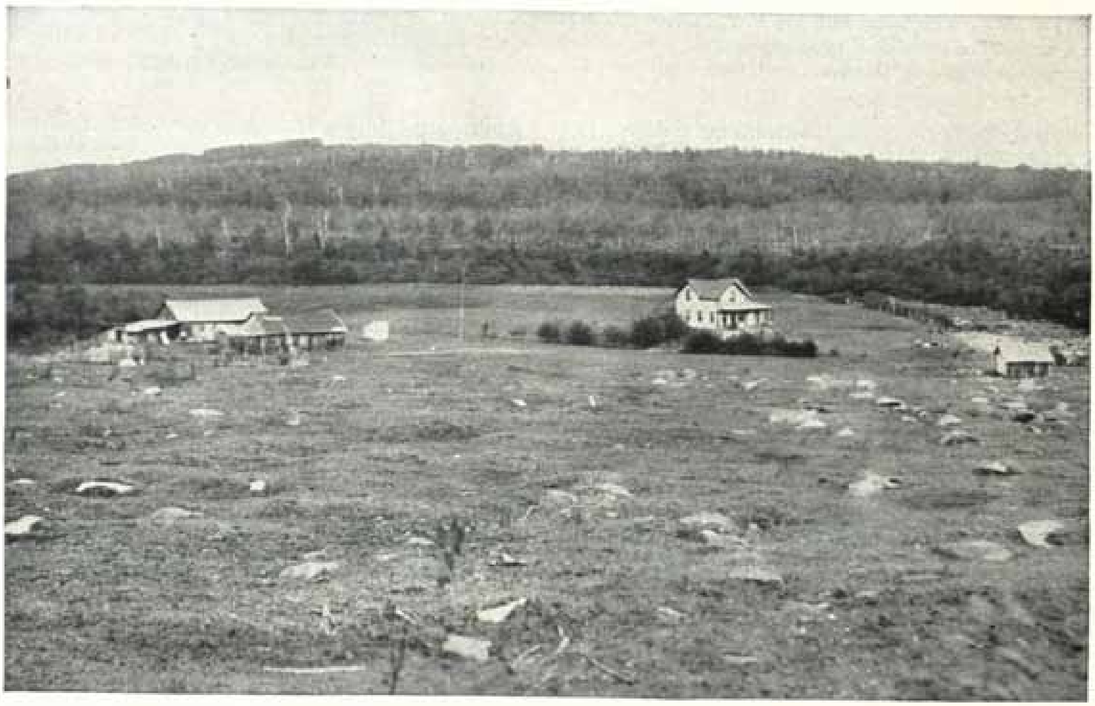


FIG. 49. One of the better farms of a cutover area in the valley of the Baptism River, Lake County, Minnesota. An island of clearing, with but one good field on the flat land near the river. The stony field in the foreground can be used only for pasture.

FIG. 50. The Spud Hill fire in the Columbia National Forest, Washington, August 5, 1937. In this view, an active fire is making progress against a strong west wind. In the foreground, young growth is making its appearance among the blackened stubs left by an earlier fire. (Courtesy of the U. S. Forest Service.)

Minnesota, for example, the total tax delinquency equals or even exceeds the assessed valuations, a very disturbing condition.

With removal of the forest cover, precipitation efficiency, though not the amount, decreases; the more rapid runoff causes soil erosion, increases flood danger, and interferes with use of the streams for all purposes: navigation, power development, irrigation, and others. Scenic attractiveness disappears and wild life is affected adversely; in extreme cases, the area becomes a waste with an economic value approximating zero.

These facts are now quite generally recognized, and with such recognition the general public has at last become aware of the desirability of restoration of the environments of many of these formerly forested areas to their former condition, insofar as that may be a possibility. Thus planning for land use, that is, formulation of recommendations for its most effective utilization under present conditions, almost invariably contemplates restoration of the forest cover in those areas where growth of a tree crop represents the most effective use of the land.

Fires. In addition to fires started by lightning, others set by man, 92.4 per cent of all, each year ravage an area in the United States larger than that of New England. Of these fires in protected areas, for which we have data as to causes, nearly 27 per cent are of incendiary origin; over 26 per cent are caused by smokers; burning of debris and lumbering account for nearly 16 per cent; campers cause slightly more than 7 per cent. The others, resulting from railroads, miscellaneous, and unknown causes, account for a trifle more than 22 per cent.

Most incendiary fires are set by individuals who expect to profit personally by securing employment in fire fighting, or from improvement of woodland pasturage. Fires caused by smokers and campers are particularly prevalent in the eastern half of the country, where the number of tourists, attracted by our increasingly accessible forest area but ignorant of the fire hazard their coming introduces, swells year by year. Fires re-

sulting from the two preceding causes, the most important, and accounting for over 50 per cent of all fires caused by man, plus others set by the burning of brush, railroads, and a number of miscellaneous agencies, are preventable in large part, and their prevention would be in the public interest.

In all, there are well over 150,000 reported forest fires each year. Of these, 75 per cent are in the South, where many are set deliberately with a view to improving the pastures. Many of the fires reported are small, but in the aggregate they burn over 6 per cent of the total forest area each year, though, fortunately, many of these fires run in previously burned-over tracts.

The list of important forest fires in the United States is so long that only a few can be mentioned specifically. The Peshtigo fire of October, 1871, in Wisconsin, one of the most disastrous of them all, burned 1,280,000 acres, and 1500 persons lost their lives. The Hinckley fire of September, 1894, in Minnesota, devastated millions of acres, burned 160,000 acres of forest, wiped out 12 towns, and cost 418 lives. Smoke was so dense as to interfere with navigation on the Great Lakes. The Cloquet fire of October, 1918, also in Minnesota, destroyed Cloquet, a sawmill town with a population of approximately 10,000, and entailed a property loss of $30,000,000. This fire even threatened Duluth. In all, more than 400 persons perished in Cloquet and the surrounding area. The Wilson River fire of August, 1933, in Oregon, fanned by a strong wind, burned 267,000 acres of standing timber, two-thirds virgin forest, during the 11 days it raged. The amount of timber destroyed by this fire equaled the entire cut for the United States in 1932. Stumpage loss alone was $20,000,000; the total loss was $350,000,000. Smoke was so dense that lights were burned at midday, and ashes fell to a depth of 2 inches in the coast towns at the time of the fire. During the dry fall of 1947, many man-set fires ravaged the forests of northeastern United States, particularly in New England, where it was necessary to evacuate the inhabitants of several communities, including those of the resort town of Bar Harbor, Maine, to prevent loss of life.

In addition to fires in our forests proper, others take their yearly toll, as in the Everglades of southern Florida during March and April of 1939. This fire devastated more than 1,000,000 acres of swamp and sawgrass. In places, it burned 3 feet deep in the muck soils, which are composed largely of organic material. Smoke was so dense that travel was rendered dangerous. Most of the wild life was destroyed, and a previously attractive wilderness was converted into a waste, to the detriment of man.

Forest fires affect everyone, either directly or indirectly, for they destroy merchantable timber and change the character of the wild life, both plant and animal, detrimentally. This decreases the national wealth. In areas where they have run repeatedly, they have likewise ruined the soil, rendering such regions almost totally unproductive and an economic liability. By their effects on vegetation cover, and often on the soil as well, they increase rapidity of runoff. This facilitates soil erosion, increases stream fluctuations, and decreases the value of rivers for all uses. Locally, they may be ranked with natural catastrophes such as volcanic eruptions, for they take a toll of both life and property, the total of which may equal or even exceed that levied by volcanic activity.

Drainage. Man has, both individually and in cooperation with others, initiated drainage projects in many parts of the world to remove surplus water from both wet and overflowed land. This has been done in the belief that an increase of agricultural acreage capable of effective use would be profitable for the individual and socially desirable for the community. In certain areas, this drainage has accompanied existing agricultural use of the land as a means of increasing production; in others, drainage has been inaugurated in advance of and to tempt agricultural occupation which has not always followed. In either case, such drainage has modified the physical environment, sometimes very materially.

In certain parts of the world such as the Netherlands, where approximately 40 per cent of the land up to quite recently in production is low-lying, and 25 per cent or more is actually below sea level at high tide, drainage is extensive, and large areas of wet and submerged land have been reclaimed for agricultural use. Even shallow seas such as the Zuider Zee have been diked and drained by pumping, and their former bottoms brought under the plow. This extensive reclamation of wet land has been made necessary by the fact that pressure of population on the land is great in the Netherlands, where approximately 9,000,000 people live in an area only about 28

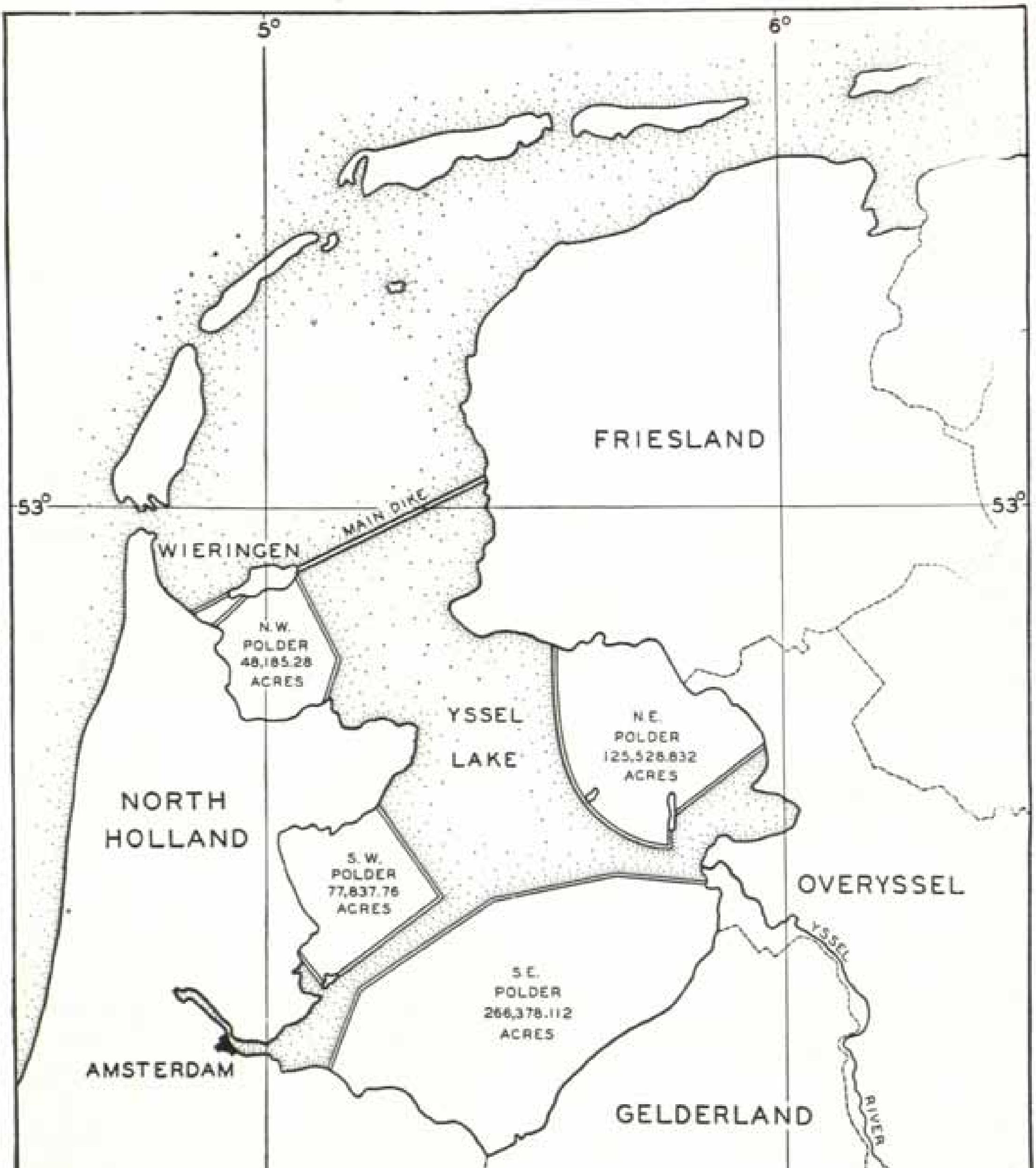


FIG. 51. Part of the former bottom of the Zuider Zee has already been reclaimed by diking and pumping, the some 270 square miles of the northwest and northeast polders now being in effective agricultural use. Eventually, with reclamation of the other two polders, the southwest and southeast, nearly 530 additional square miles of former sea bottom will be added to the productive area of the Netherlands. Yssel Lake, the shrunken remnant of the formerly more extensive, shallow Zuider Zee, will then cover only about 1,350 square miles and will be left to serve fishing and trade interests. The water of this lake is now fresh, for the sea is cut off and local drainage has diluted and removed the salt water over the sluices which supply outlets for surplus water. Therefore it is of considerable value for irrigation in dry seasons, and for watering livestock at all times.

per cent greater than that of Maryland, which had a population of 1,821,244 in 1940.

The Dutch have waged a long and successful war with both the sea and their rivers. Dikes have been built to restrain the sea; river flow has been confined between levees; old channels and ponds have been filled; and canals have been built to carry off surplus water. Since so much of the present land surface is below sea level, surface water must often be removed by pumping into these canals, which are above the level of the cultivated fields. Where the reclaimed land is former sea bottom, it is also necessary to rid the soil of salt before it is capable of effective agricultural production. Even after all this has been done,. many of the fields are so soft that pasturage of cattle is impracticable, and special methods of cultivation must be employed.

The drainage system of the Netherlands is both extensive and complex. Initially constructed and operated by associations of local landowners, the government has of late years assumed a large measure of control. This is because of the great importance of reclamation of wet land in the economic life of the country. The activities of the Dutch in the reclamation of wet land have obviously modified both the natural and cultural environments in the direction of greater desirabil-

Fig. 52. The greatest dike in the Netherlands, started in 1924 and completed in 1932, extends in an easterly direction from Wieringen, closing the entrance to the Zuider Zee. By construction of the additional dikes shown in Fig. 51, and by pumping, some half million acres of former sea bottom have been reclaimed. The remnant of the formerly more extensive Zuider Zee is known as "Yssel Lake." In this view, the level of the water of the North Sea at the left stands 15 feet higher than in Yssel Lake at the right, so that the reclaimed land could be easily flooded by opening the dikes. The main dike shown above, with a bicycle path at the left and a brick-edged road to its right, serves as a highway, in addition to keeping out the sea. (Courtesy of *Life Magazine*.)

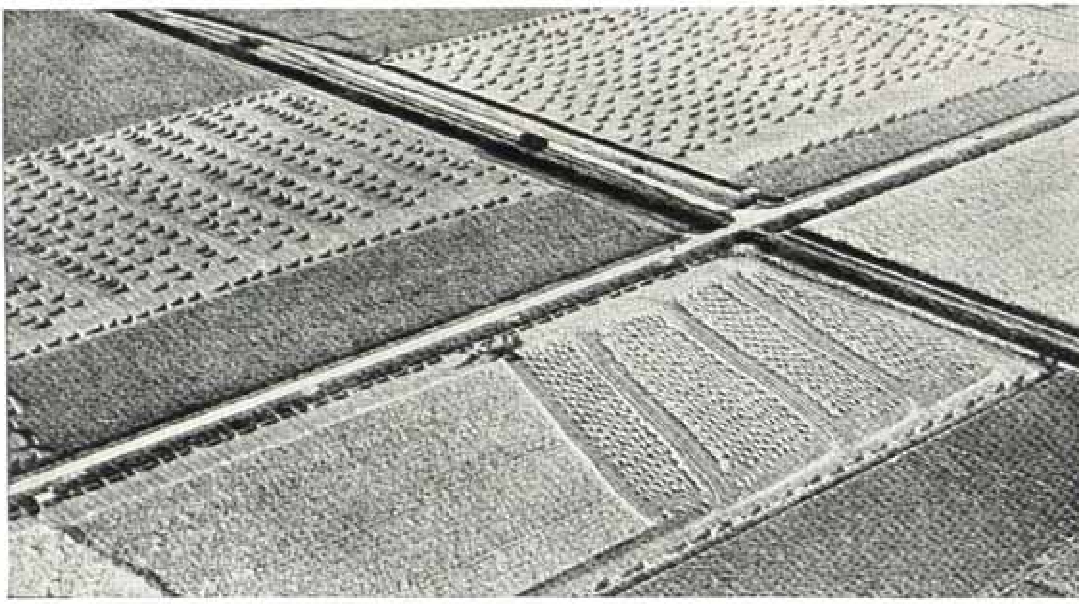


FIG. 53. A typical agricultural landscape showing prewar use of the former bottom of the Zuider Zee in the Wieringenmeer, or the northeast polder shown in Fig. 51. In some of the fields, crops are still ripening; in others, the grain has been cut ond shocked. In the central part of the view, farm buildings are grouped on the slopes of one of the dikes, where drainage is better and the farmyards will be relatively dry. Two dikes cross the area at right angles to one another. These serve as highways and also to enclose the fields, so that cattle may be pastured if desired, short temporary fences set on the bridges across the canals completing the pasture fence on the dike side. The main dike protecting this polder was breached by the Germans on April 17, 1945, but by August 5 of the same year, repairs had been effected, and crops were harvested in 1946. (Courtesy of the Netherlands Information Bureau.)

ity. Unfortunately, many of the dikes were cut and the work of years destroyed during the period of German occupation. This undesirable modification of the environment worked a great hardship on the inhabitants, particularly in the inundated regions. To restore the fields flooded in this manner to their former productive capacity will require much work and sometimes several years. However, the damage done is not irreparable and in time the landscape will once more assume its former appearance and capacity to support population.

In the United States the land drained, or needing drainage before it can be used for growing crops effectively, falls into three major classes: (1) alluvial or river swamps, particularly those of the larger rivers such as the Mississippi and its principal tributaries; (2) poorly drained areas in the glaciated portions of northeastern United States, sometimes flat tracts with poor natural drainage, and, in other cases, depressions without natural outlets; and (3) coastal swamps and wet lands of the Atlantic and Pacific seaboards and the Gulf Coast, many of them tidal or salt marshes. In addition to these major classes of drained land and wet land needing drainage before it can be used to advantage for crop production, irrigation often brings in its train a drainage problem in the "seeped" lands which result from the application of irrigation water, and in the alkaline lands normally present in arid land under ditch. Adequate artificial drainage of such lands is difficult, expensive, and in many cases economically impossible. In 1940, the acreage so drained amounted to only about 4 per cent of the total area in all operating drainage projects reported by the census.

In the United States, the acreage of fertile land ready for agricultural use without expensive drainage has been sufficient to meet demands in the past. Hence there has been no necessity for bringing the bottoms of shallow seas into production, as in the Netherlands. Quite recently, indeed, we were even withdrawing formerly cul-

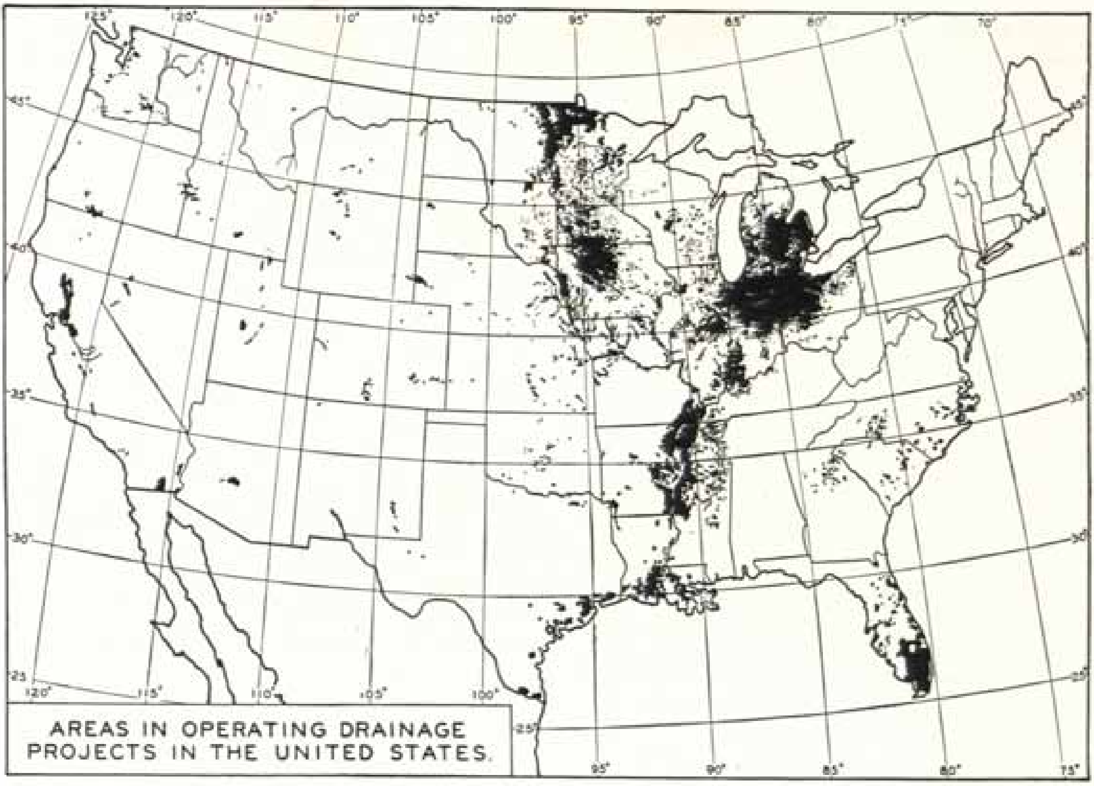


FIG. 54. Drainage in the Upper Mississippi Valley is in glaciated areas with immature or poorly developed river systems; in the Lower Mississippi Valley, in alluvial deposits, or those of the flat land bordering the rivers. In southern Florida, the soils made available for use are mucks, or the organic soils of the Everglades. West of the 100th meridian, drainage is largely in connection with irrigation. (After the U. S. Census.)

tivated fields from use to avoid a surplus of agricultural products, and it may well be that this will occur again in the future. Under such conditions, drainage in this country has normally been limited to those areas where the cost of removal of excess water was not great, and where climate, soils, and accessibility to market indicated the probability of success for agriculture.

The land in the United States which needs drainage before it can be used effectively for crop production is concentrated in two principal areas: (1) the South, with 65 per cent of the total; and (2) the Lake States, with 55 per cent of the balance. The remainder is widely scattered in location.

At first, reclamation of wet land was by individuals; the units drained were small; and the cost per acre was not great. Eventually, most of the small projects which promised a profit were developed, and the cooperation of groups, and even of political subdivisions, became necessary for effective drainage of larger units of land. Such cooperative drainage was especially rapid between 1905 and 1919. This rapid increase in reclamation of wet land resulted from increased prices for farm land and high prices for agricultural products, especially during the later part of the period. In the preparation and use of this vast acreage, almost equal in extent to the combined areas of Illinois, Indiana, and Ohio, the two-thirds of the area in forest were cleared, thus altering environmental conditions materially, not only as a result of lowering the ground water level by ditches but by deforestation as well.

Sometimes the environmental changes produced by drainage of wet or overflowed land are, in their total, to man's advantage. This is true when the drained land passes into profitable agricultural use, as is frequently the case, especially where drainage is undertaken in connection with

going farm enterprises which already yield moderate or satisfactory returns. All too often, however, reclamation of our marshes and swamps has been undertaken in the past at an expense not commensurate with any present or probable future returns from agricultural use, and, often as well, far in advance of any need of the land for agriculture. This is especially true of those cases of drainage of the wet lands of the higher latitudes in glaciated areas where peat soils, climatic hazards, and distance from market all combine to eliminate any possible profitable use of the drained area.

Irrespective of whether desirable or otherwise, ground water level is always lowered by artificial drainage, for that is its objective. With depression of the water table, low water stages of the rivers become even lower, and their desirability for a long list of uses is decreased. Lake levels are likewise lowered; shallow lakes may even disappear completely. This may be of considerable importance where lakes afford resort possibilities.

As a consequence of these effects on water levels, wild life dependent on our marshes, lakes, and streams for food supply and breeding grounds disappears. It is estimated, for example, that the breeding grounds for waterfowl in the Upper Mississippi Valley and the Lake States do not today exceed 1 per cent of their original extent, this decrease of 99 per cent being almost entirely the result of artificial drainage. Areas which formerly swarmed with almost countless numbers of waterfowl now have few or none as a result of man's activities. Not only have the breeding places been destroyed, but increased flood danger, resulting from the more rapid runoff ensured by man-made drainage lines, creates a hazard for fish, shellfish, and the wild life of the overflowed bottomlands. Sacrifice of our wild life entails an enormous environmental change, both directly and indirectly, as well as an important financial loss. With drainage of marshes and swamps, their organic soils dry out during protracted periods of dry weather. In this condition, they will burn when ignited, which occurs not infrequently. Such fires may run for years, dying down during wet weather, blazing up when the soil dries out. Then, fanned by strong winds, they often spread to adjacent forested upland areas.

From the foregoing consideration, it is obvious that each contemplated drainage project should be judged on its individual merits, since there is no other logical method of reaching a decision as to whether a given area should be drained other than to consider conditions in the area for which drainage is contemplated. In the past, however, it has all too frequently been true that the detrimental effects have not been accorded the importance they deserved. Today, therefore, we are taking steps to rectify the mistakes of the past by spending money to create artificially what we have in the past spent money to destroy: marshes, swamps, and lakes supplied by nature without cost.

QUESTIONS AND EXERCISES

1. How does man differ from the animals with respect to limitations imposed by the environment? How effective is man in altering the natural environment by comparison with the animals? Why? Is his effectiveness increasing or decreasing? Why? Name the human activities effecting environmental change.
2. How does our present forest compare with the original resource? What types of forest and what kinds of trees compose our forest resource? What effect has this had on our consumption of forest products?
3. Why was the forest originally considered only as an obstacle to agricultural use of the land? How have economic conditions forced reckless exploitation of the forest resource? How can taxation force unwise cutting of timber?
4. What substitutes are now taking the place of wood for certain uses? Why does tax delinquency increase in an area with exhaustion of the forest resource in many parts of the United States? How can this be prevented?
5. What are the most common causes of forest fires and what is the relative importance of each? Why are incendiary fires of such common occurrence? What are the objectives in setting such fires?
6. Under what conditions do forest fires assume serious proportions? Why are forest fires most common in the South?
7. Where are the Everglades? Why are the soils of this area mucks? Why will they burn? What are the most important of the effects of forest and swamp fires?
8. Describe some of the great forest fires of the United States. What losses did each cause? If possible, report on one of these fires, or one of equal importance, in some detail.

9. In what European country is artificial drainage very extensive? Why has this been necessary? In what respects is this drainage different from that practiced in the United States? How does the drained land of this European country compare in productivity with that of near-by, undrained areas?
10. What are some of the handicaps to use of the land reclaimed by draining such shallow seas as the Zuider Zee? How is the surplus water removed from such reclaimed land?
11. Name the three major classes of land drained in the United States, or needing drainage before it can be used for growing crops to advantage. Why is drainage sometimes necessary in connection with irrigation projects in the United States? Are such drained areas extensive? Why?
12. During what period was artificial drainage of land most rapid in the United States? Why? Where are these drainage projects most numerous? Why? How many acres of land were included within operating drainage projects in the United States in 1940? How large is this area by comparison with that of your home state?
13. Under what conditions does artificial drainage pay? Under what conditions is it detrimental? Illustrate by examples, from your home state if possible.
14. How does drainage alter the environment? What are some of the most important of the detrimental effects of artificial drainage? How does artificial drainage tend to increase the danger of forest fires? What steps are we taking today to repair the damage done by unwise drainage in the past? What advantages will be gained by such projects?

SELECTED REFERENCES

Parkins, A. E., and Whitaker, J. R., *Our Natural Resources and Their Conservation*, John Wiley and Sons, Inc., New York, 1939, Chaps. VIII, X, XI, and XIX.

These chapters are devoted to the problems of reclamation of wet and overflowed land; our forests, past and present; essential measures in forest conservation; and conservation of wild life. Treatment is clear, comprehensive, and reasonably up to date, the last making this reference of special value.

Van Hise, C. R., *The Conservation of Natural Resources in the United States*, The Macmillan Company, New York, 1918, Parts II, III, IV.

This standard text on conservation contains an excellent discussion of our water, forest, and land resources in the chapters cited. For many years the standard text on conservation, it is still, though somewhat old, of value to supplement the discussion in your text, for the *principles* of conservation have not altered with the passage of time; only the statistical material is outdated.

Chapter Nine

THE CHANGING ENVIRONMENT: HUMAN AGENCIES PRODUCING CHANGE—GRAZING, THE EXTRACTIVE INDUSTRIES, AND IRRIGATION

Grasslands. The world's natural grasslands are both extensive and widely scattered. In all, they occupy approximately 40 per cent of the total land surface of the earth. This is more than one and one-quarter times the extent of the forested, and almost double that of the desert area. Such grasslands in the United States, located for the most part west of the Mississippi River and east of the Rockies, comprise essentially the same percentage of the total area of this country that they do for the world as a whole. This vast grassland area of some 22,500,000 square miles, nearly twice the size of Africa, is split up into many subdivisions, both large and small. Some are located in rather high latitudes or far from the equator; others are in the tropics, where temperatures are high throughout the year. (See Fig. 229.)

In general, grasslands are confined to regions of precipitation deficiency, either total or seasonal. This is because grasses will flourish where the annual rainfall is insufficient to support a true forest, as well as in areas where the dry season is too long to permit more than a few trees in favored locations, or scattered, woody, drought-resistant growths. An exception to this general rule is afforded by the prairies of Illinois and other similar grasslands of the central United States, where rainfall is ample in amount and normally well distributed throughout the year. There, the grasslands represent an inheritance from the past rather than a plant response to present environmental conditions.

Both in the United States and elsewhere, grasslands differ greatly in appearance from region to region. This variation is in major part the result of climatic limitations which affect the range of individual plant species. Thus the natural grasslands of the tropics are quite different in character from those of intermediate latitudes where we live, and they likewise present a somewhat different opportunity to man than do those where temperatures are low part of the year.

Even in the United States, the natural grasslands are of two types: (1) prairie in the better watered eastern areas; and (2) steppe in those farther west, which suffer from a precipitation deficiency. In the true virgin prairie, bluestem, a grass, grew to heights of 10 to 12 feet under favorable conditions. By contrast, in the drier Great Plains, the shorter grasses of the steppe, especially grama and buffalo grasses, where characteristic elements of the plant life. In the transition zone between the true prairie and the short-grass plains, the vegetation was mixed in type and of intermediate height. Long before the advent of white men, grasses had captured the undissected interstream areas of both the present prairie and steppe regions completely; only in sheltered valleys and along stream courses did trees establish a foothold. Thus grasses dominated the landscape, which varied only in color with the changing seasons. Associated with this sea of waving grasses was a native fauna including bison, antelopes, wolves, coyotes, and other beasts of prey, plus rodents, among them the prairie dog, each kept in check by the others.

With no experience except that acquired in forested areas of the eastern United States and northwestern Europe, man invaded this vast grassland domain and proceeded to upset the balance of nature by his activities. In many places the land passed under the plow with resultant

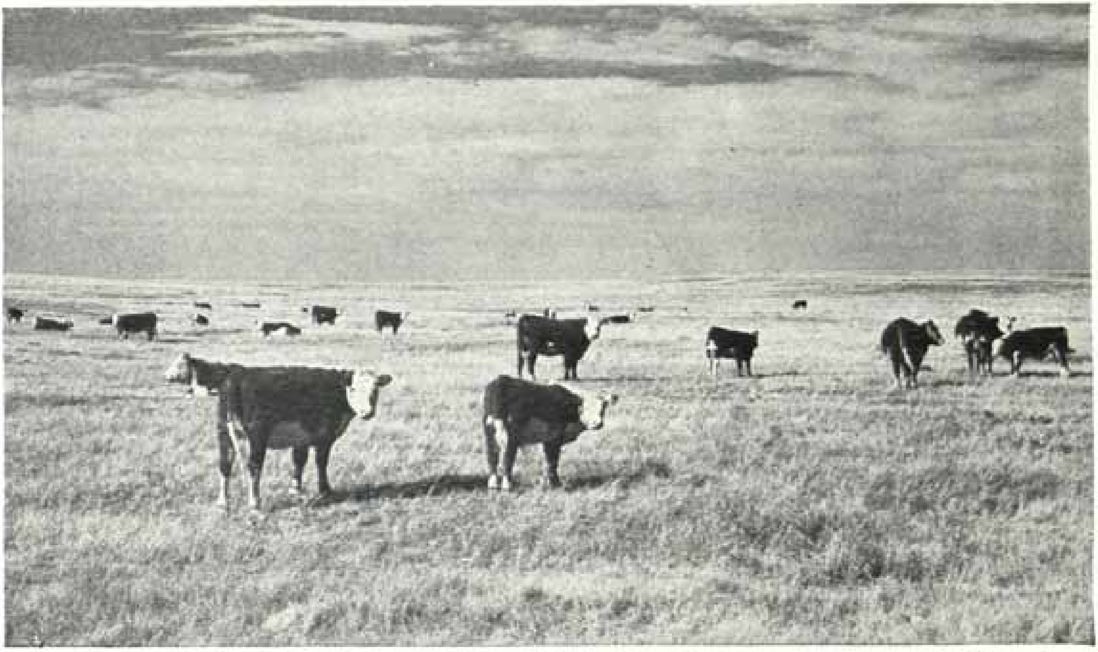


FIG. 55. Hereford cattle grazing on good range land, where the short-grass cover has not been damaged by overgrazing. The Jim Heninger range, 10 miles north of Roundup, central Montana. (Courtesy of R. V. Hufnagle, U. S. Soil Conservation Service.)

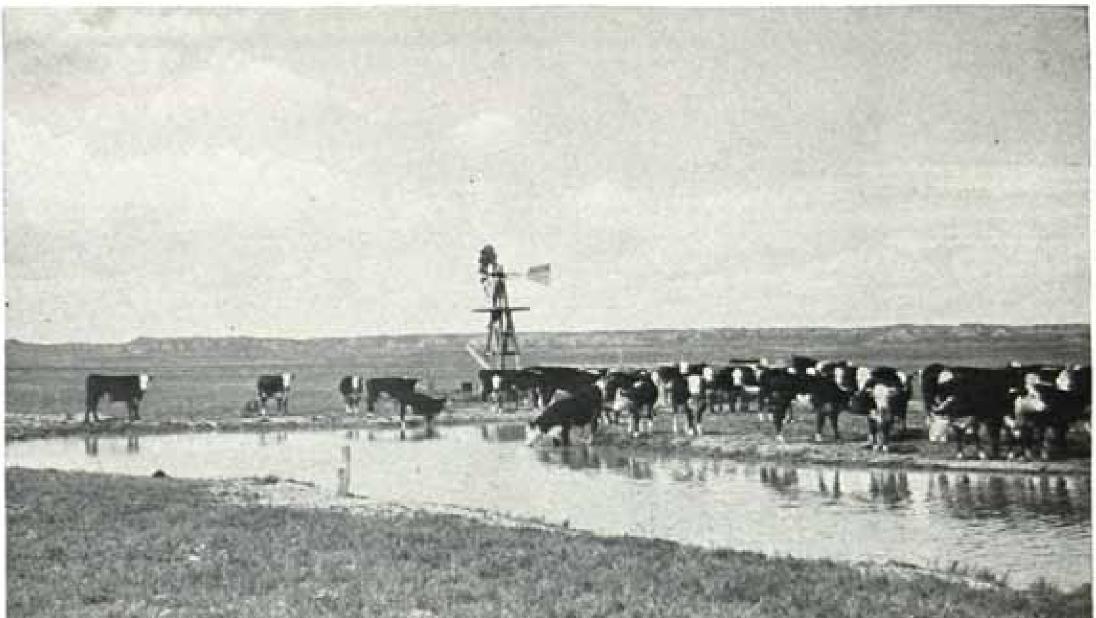


FIG. 56. Hereford cattle and a stock-watering pond on the Carl Spencer range, about 7 miles west of Veteran, in the Goshen Hole area of southeastern Wyoming. Before overgrazing, which causes rapid runoff, streams and natural waterholes supplied drinking places for cattle in the short-grass plains. This pond, however, fed by waste water diverted from the nearby highway, is artificial. During exceptionally dry periods, the windmill is used to pump additional water into the pond. (Courtesy of Orville K. Blake, U. S. Soil Conservation Service.)

destruction of the native grasses. When this occurred in the better watered areas of the tall-grass prairies, agricultural use of the land proved successful and farming operations were profitable, with *feeding* but not *grazing* of livestock an important part of the regional economy. This use of the grasslands will be considered more fully in the following and other chapters.

In the drier steppe grasslands of the Great Plains, both the character of the vegetation and the soils in which it grew indicated a precipitation deficiency, in both amount and distribution. This should have served as a warning that the best use of the land was for the grazing of livestock, not crop production. Nevertheless, some of the "prairie" sod was destroyed by plowing in an attempt to grow crops. During the wetter years this met with considerable success, but during the frequent drought periods, often several years in length, this was not true. Turning the sod wrong side up in these grassland areas not suitable for agricultural use was followed by undue drying out of the soil during the periods when rainfall was lacking. Then strong winds shifted the loose surface materials and caused severe dust storms, to be discussed more fully in later chapters.

Manifestly, these drier grasslands offered pasturage for livestock, but not opportunity for the profitable growing of crops, which could later be fed to animals on farms. Also, when grazing was practiced intelligently, it produced no greater drain on the grass cover than that caused by the former native animal population. However, overgrazing, in an attempt to secure an immediately greater profit even at the cost of eventual loss, rapidly decreased the carrying power of the range by destroying much of the vegetation cover. This was especially true of the more valuable elements or those which afforded the best pasturage for livestock. After the grass had been destroyed in this manner, it reestablished itself with great difficulty and very slowly in these dry regions, where natural conditions for plant growth are none too good at best. Further, introduced plants invaded these grasslands, in many cases displacing the original elements of the vegetation completely, so that the ground was covered for miles with a blanket of plant growth valueless for the support of livestock. With overgrazing, also, where the vegetation cover had been destroyed, the soil was no longer held in place by plant roots. Therefore it fell an easy prey to both strong winds and running water, and erosion became a

FIG. 57. A man-made "desert" resulting from misuse of natural opportunity in Sherman County, northeastern Texas. Stripped of plant life by man and denuded of soil by wind, it will be years before this area can be restored to something approximating its former desirability. (Photo by McLean, Courtesy of the U. S. Soil Conservation Service.)

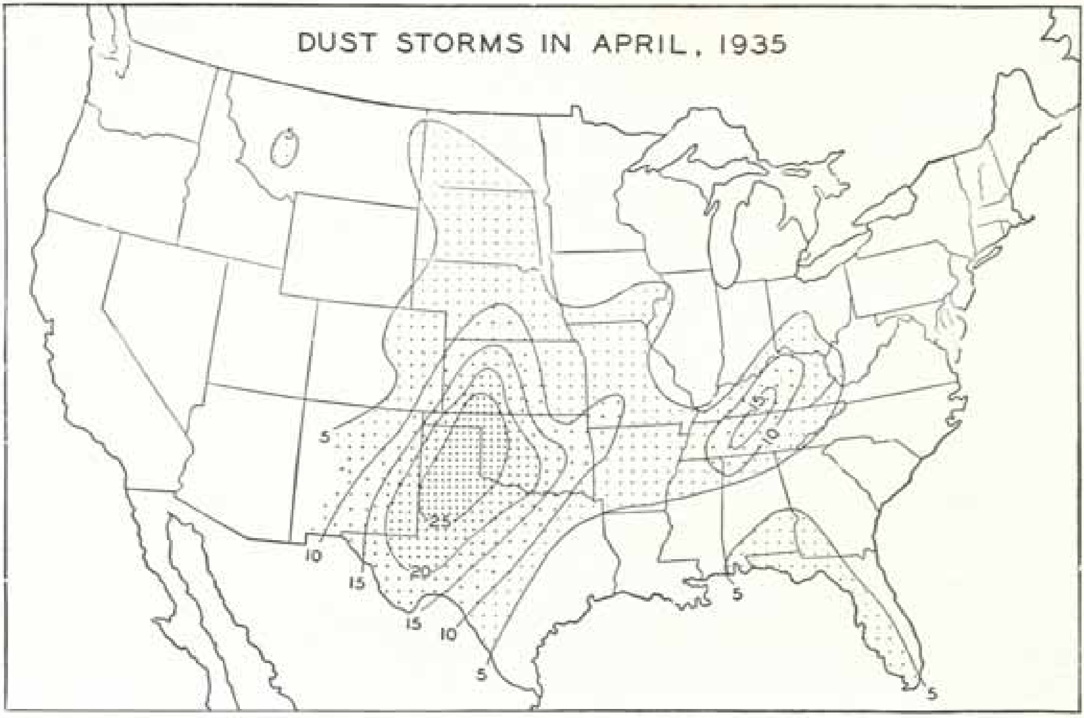


FIG. 58. With overgrazing and attempted cultivation in the Great Plains, dust storms have become frequent and serious during the late spring and early summer, especially in the drier years. The map above shows the number of days with dusty conditions or dust storms in the so-called "Dust Bowl" during April, 1935, a dry month of a dry year. (After the U. S. Weather Bureau.)

serious problem. Insofar as wind was the effective agency in soil removal, this was evidenced by the increased number and severity of dust storms.

The animal population of the dry grasslands likewise altered with man's misuse of natural opportunity. Prior to white occupation, rodents were kept in check by predatory animals, but with destruction of the latter, animals such as the prairie dog increased objectionably in numbers. This decreased the carrying power of the range or even necessitated enormously expensive eradication programs to keep it in profitable use. In extreme cases, the costs were so prohibitively high that abandonment of limited areas was necessary. Not only did the rodents increase in this manner with the killing off of their hereditary enemies, but it is probable that other objectionable elements of the fauna, such as grasshoppers, found that human misuse of the land for grazing improved conditions for their rapid multiplication in numbers.

Thus man, in considerably less than 100 years, has materially modified the environment of the grassland areas of the United States. He has destroyed almost completely certain valuable elements of the native vegetation; he has introduced objectionable plants; he has produced conditions leading to an increase of the rodents, and probably to that of certain insect pests as well; he has facilitated erosion by both wind and water; in some cases he has converted a previously desirable grazing area into one which is today a definite liability. These are all changes to his detriment, and all unnecessary.

Man has also produced these same effects in other parts of the world. In the Pampa of the Argentine, for example, large herds of cattle and horses and flocks of sheep have replaced the native animals, and prejudicial animals such as rats and dogs have become veritable plagues. At the same time, the vegetation has been affected by the grazing and trampling of livestock. Many elements of the former vegetation cover have

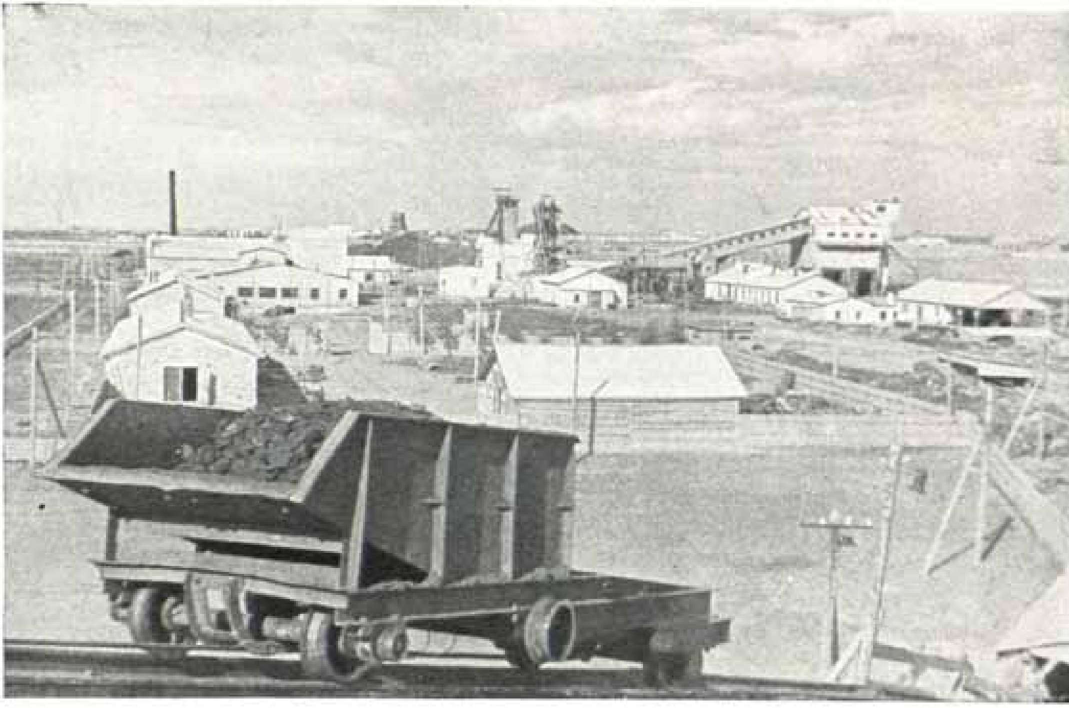


FIG. 59. A coal mine in the Karaganda coalfield. Located in southwestern Siberia, this and many other mines of the area supply coal needed by the industrial plants which are located in the region between the Caspian Sea and the Tien Shan. Initiation of coal mining in this basin, the third most important in the U.S.S.R., has produced marked environmental changes, both locally where the coal is mined and in those areas where it is used in the great manufacturing centers which have developed east of the Urals. (Courtesy of Sovfoto.)

thus been destroyed by intensive grazing and replaced, in the absence of the former competition, by less desirable pasture grasses. Introduced European plants have also found a foothold and spread so rapidly as to change the entire aspect of the area. In some places, for example, the land is covered as far as one can see with a dense growth of cardoon thistle. The result is that today only one-fourth of the wild plants of the Pampa are native to the region.

Extractive Industries. The extractive industries such as mining, by contrast with agriculture and most of man's other economic activities, which can be carried on for indefinite periods of time in a given locality if proper procedures are followed, exhaust the resources which make them possible within relatively short periods of time. This is true irrespective of the efficiency of operations. In view of the fact that their life is so limited, and that the products ensured by their operations are so essential to man at the present stage of his development, all proper steps should be taken to prolong the life of the extractive industries. In the formulation of plans to assure this desirable objective, all factors bearing on the problem should be considered, including present needs as well as those of the future.

Mining. Modern industrial development is dependent on the exploitation of commercial deposits of mineral wealth, both metallic and nonmetallic. Following such exploitation, without which our present industrial civilization would be impossible, marked environmental changes occur. In the areas of production, the economically valuable mineral resources are eventually exhausted and the resulting change is detrimental. Seldom if ever is there any gain without an accompanying loss. In communities based on mining, the gain from exploitation of the mineral resource is temporary; the loss is permanent, for, with exhaustion of the mineral resource which brought settlement into existence, abandonment

occurs. The West, for example, contains many of these "ghost towns," peopled only by memories of a glorious past and an occasional old settler who "lives" in that past, with the hope that some lucky strike may restore the former prosperity.

This same mineral wealth, extracted at the cost of eventual loss to the area from which it comes, is utilized in other parts of the world to erect buildings, produce machinery, and in other ways, all of which modify the cultural environments of the using but nonproducing areas, both directly and indirectly. Thus an extractive industry such as mining affects not only the environment of the areas endowed by nature with mineral wealth, but likewise enables man to modify his environment elsewhere.

It will be noted that in areas dependent either solely or in major part on mining for support the only asset of the natural environment offering substantial economic opportunity is the commercially exploitable mineral wealth. When that has been dissipated, the principal basis for human occupancy disappears, and the mining industry and those dependent on it for support move on to new fields. These in turn go through the same stages of boom development, temporary prosperity, and relapse into abandonment, if no other basis for economic activities develops to parallel or finally supplant mining operations. Such abandoned mining locations pose distinct problems of areal utilization, no less serious in many instances than those of deforested regions, or where overgrazing has destroyed the range. Their multiplication in number and increasing extent emphasize the desirability of conservation, or wise utilization of mineral deposits, to provide against the inevitable future when these resources will be less abundant, and to put off as long as possible the time when some, or all, are exhausted completely.

Taking a long-time view, the mineral resources are a public heritage, probably administered to best advantage by private enterprise, so regulated that areas ruined by unwise exploitation will not multiply needlessly. To ensure this result, all commercially important mineral deposits should be developed without unnecessary waste, and with a view to securing maximum yields and as nearly complete recovery as possible over a considerable period of time, but without unwarranted costs, which must be paid eventually by the consumer. Further, in the extraction of high-grade deposits, consideration should be given those of low grade, not economically valuable today, so that their mining may be practicable if later technological advances should make this a possibility. In other words, the extractive industries should, in the interest of the public as well as that of themselves, forego an exorbitant present profit, secured by "skinning" the resource, for the sake of a longer period of gain and a greater total return. This point of view, which makes for a longer life of the reserves and a greater total profit, is one commonly taken in the larger and more enlightened operations, in the absence of a local taxation policy which makes it an impossibility. However, it is much too frequently not the one of the smaller, less efficient marginal producer, whose operation at a profit is possible only with reckless mining practices which dissipate the mineral deposits with unnecessary rapidity and excessive loss. Such a conservation policy as has been outlined, or one designed to utilize the resource in the public interest, contemplates cooperation by both the operators and the public, the contribution of the latter being a reasonable attitude as regards taxation and profits; that of the former, a willingness to take a long-time view and sacrifice the present to some extent for a future benefit.

Irrigation. In bringing the drier areas west of the 100th meridian in the United States into agricultural use, irrigation, or the artificial application of water, is often practiced as a method of making profitable crop production possible. The first irrigation enterprises were mostly small individual projects, followed by somewhat larger cooperative ventures. Still later, those constructed by the Federal government as part of a comprehensive program of reclamation brought even larger acreages under ditch by the expenditure of huge sums of money to provide water for tracts private capital could not develop at a profit. Irrigation in both private and government projects has modified the original environment, converting formerly unproductive areas and others of low productivity into ones of greatly increased actual or potential production.

Man, tempted by conceived opportunity, invades such areas under ditch in considerable numbers. He builds houses, barns, and other structures; puts up fences; constructs roads; installs telephone lines; plows the land; and plants crops and trees, thereby leaving the observable

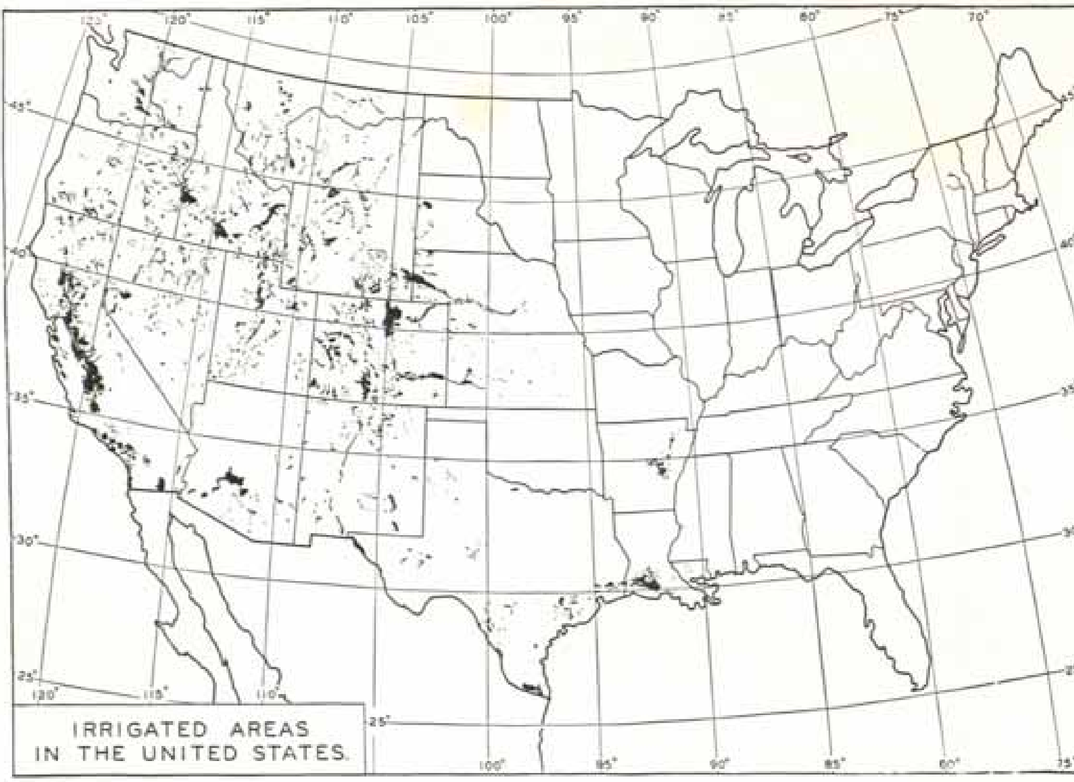


FIG. 60. Most of the irrigated areas of the United States are located west of the 100th meridian, where rainfall is deficient in amount. In the Lower Mississippi Valley, irrigation is in connection with rice production on flooded fields. (After the U. S. Census.)

impress of his activities on the cultural landscape. Visually, an irrigated area with its green fields and shade may present a very attractive picture, particularly to one who arrives in such an oasis after many miles of travel through bordering unirrigated country, the contrast thus afforded being so great that the attraction is magnified in the absence of any immediate, satisfactory basis for comparison. Even granting that such irrigated areas are as attractive as they may appear to be, it by no means follows that the change produced by the application of irrigation water represents a desirable alteration or a permanent betterment of environmental conditions, taking all the facts into consideration. Though attractive to the casual view, it is often true that the results obtained by irrigation do not warrant the time and money spent to effect the transformation from semiarid or desert conditions to green fields, for expenditure of the same effort and money elsewhere would have produced results of greater value to society. Further, irrigation is always accompanied by certain detrimental effects which, over an extended period of time, frequently more than offset the advantages accruing from the artificial application of water.

Much of the irrigation water used in arid areas under ditch in the western United States contains a surprisingly high percentage of dissolved mineral matter, often objectionable in character. It is estimated, for example, that in the Imperial Valley of California the water applied yearly to each cultivated acre carries approximately 4.25 tons of salt in solution. Over any extended period of time, the large amount of salt added with the irrigation water may produce distinct damage, reflected in decreased productivity.

In dry areas, leaching, or the removal of soluble mineral matter or "salts" from the soil by percolating water, is slight or absent. This is because, though rain sinks into the ground a short distance, dissolving mineral matter in its

downward course, it later returns and deposits this dissolved load in the surface layers, as the water evaporates and the soil dries out. In a state of nature this concentration of minerals may not be objectionable, for the amount of water which falls as rain is small, and it penetrates only the top few inches of the soil. Therefore it does not accumulate any great load of dissolved mineral matter. When irrigation water is applied, however, concentration of salts in the surface layers may increase to an extent that is distinctly detrimental. In extreme cases, an accumulation of alkaline material may form on the surface of the ground as a glistening white deposit, an "alkali spot," in which nothing will grow.

Occurrence of these spots is in many cases the result of unwise and excessive application of irrigation water, it is true, but the possibility of increasing alkalinity to a degree which eliminates production is always a hazard, irrespective of the care an individual farmer may exercise in his use of water. This is because water applied by others may travel underground for considerable distances, thereby accumulating an excessive load of alkaline salts before returning to the surface. Thus this load may be deposited far from the farm where the water was applied. Practically all irrigation districts which have been occupied for any appreciable length of time show such alkali spots, some only a few feet in diameter, others covering many acres.

Another change in the physical environment

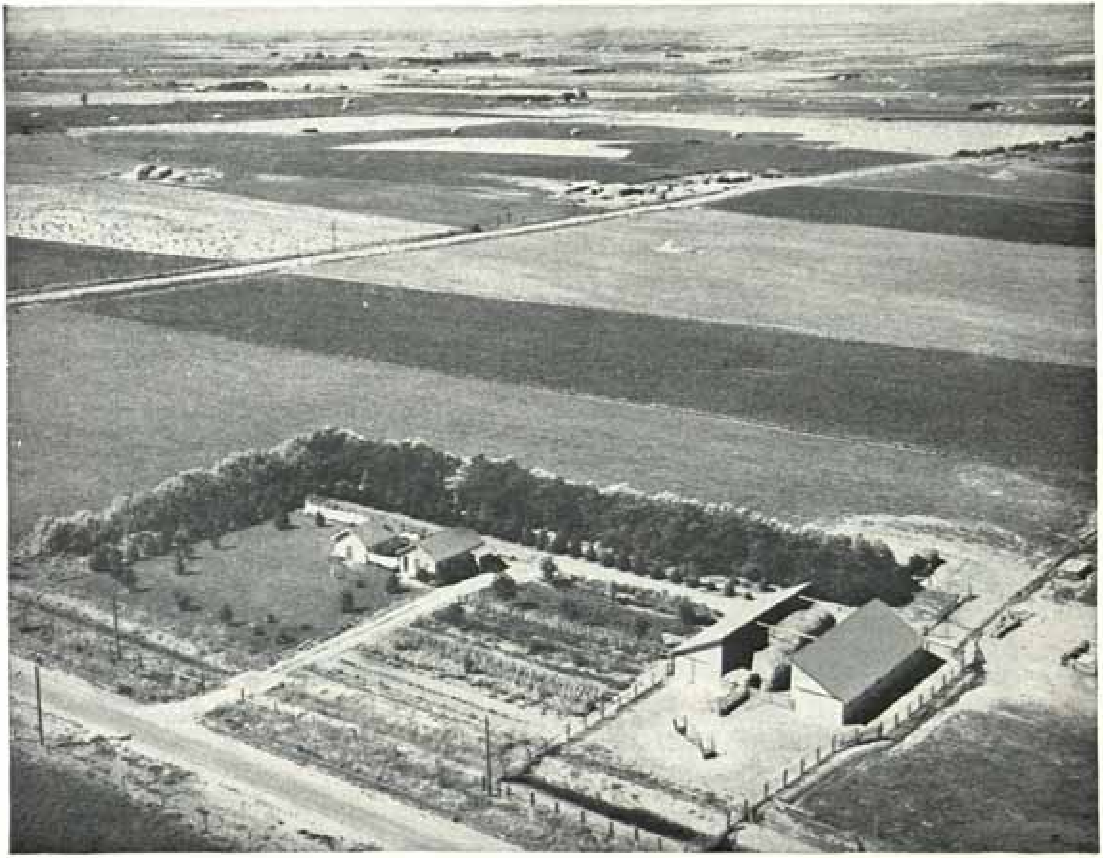


FIG. 61. An attractive farmstead in the Kittitas Valley, 12 miles southeast of Ellensburg, Washington. The windbreak, made possible by irrigation and grown in 7 years, consists of trees ranging from 6 to 35 feet in height. These provide protection for the farmstead and garden, and winter shelter for livestock. Such an oasis as the one in which this farm is located presents a great contrast to the surrounding semiarid country showing indistinctly in the background. (Courtesy of 41st Division, Washington National Guard, and U. S. Soil Conservation Service.)

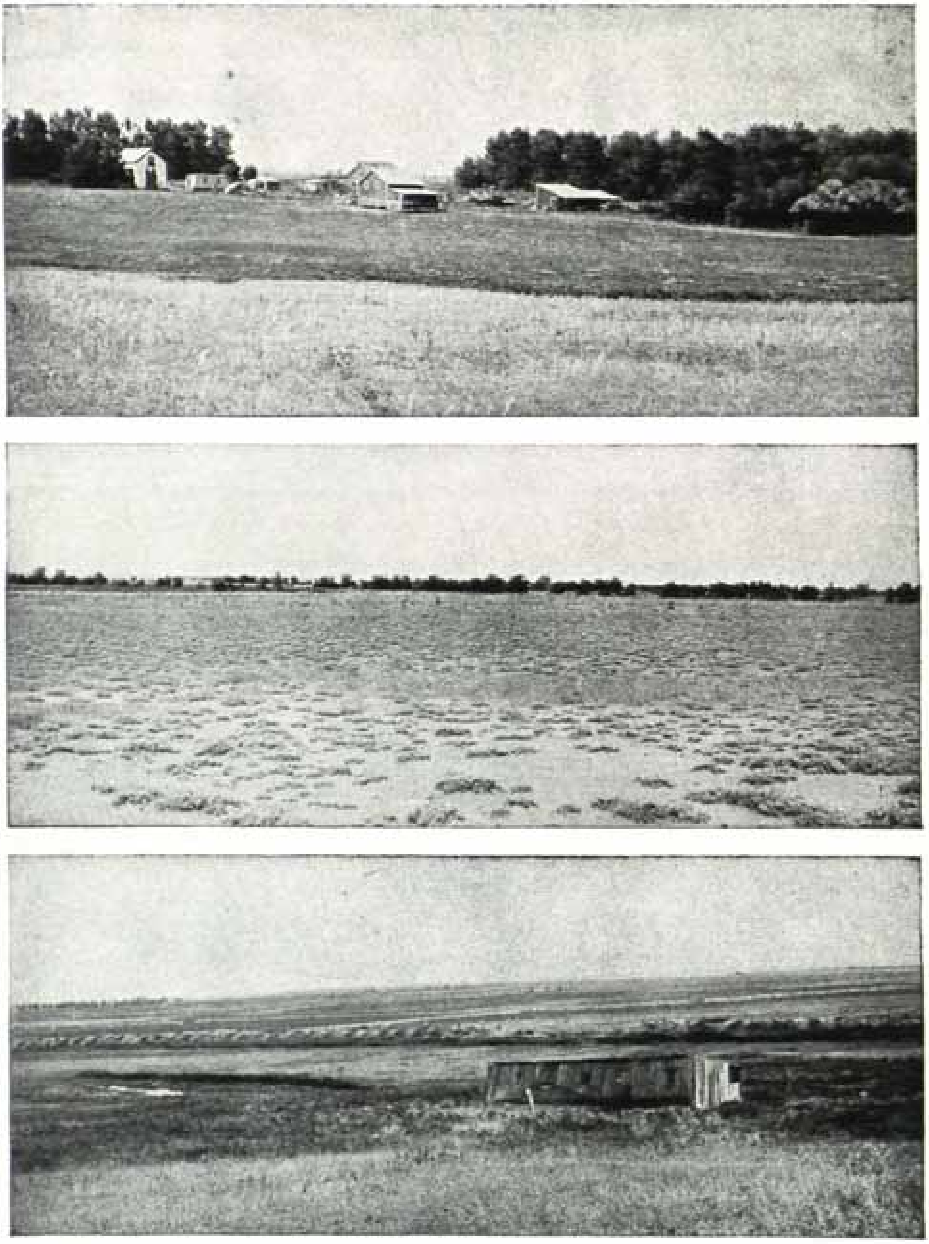


FIG. 62. *Top:* An average farmstead in the central part of the Belle Fourche Federal Irrigation Project, south of Newell, South Dakota. Irrigation has made possible the trees which serve to break strong winds, and to afford some measure of attractiveness to the landscape.

Middle: Alkali spot, 2 square miles in extent, caused by seepage. Located in the Arpan Plain, the western portion of the Belle Fourche Federal Irrigation Project, South Dakota. Originally cultivated but now valueless, it supports only a scanty growth of "rabbit grass." The trees on the edge of the higher "unseeped" land in the background mark the location of a "lateral" or secondary irrigation ditch.

Bottom: The light that failed. An abandoned farm in the Belle Fourche Federal Irrigation Project, about 1½ miles south of Newell, South Dakota. The dilapidated building at the right is an old barn; the house has been destroyed. In the middle, extending from right to left, is a "lateral." Abandonment of this farm was forced by seepage and increasing alkalinity which made cultivation no longer profitable. (Courtesy of R. H. Brown.)

which occurs frequently in irrigated areas is that the soils become waterlogged. In a state of nature, losses by evaporation are so high as a result of the dry air that, in association with the small amount of rainfall, seldom if ever does water accumulate in the soil in objectionable amount. With application of irrigation water, this natural balance between precipitation and evaporation disappears on some of the lower land, with the result that the soils of such areas become so thoroughly saturated with water, or waterlogged, that crops cannot be grown effectively, and the land passes out of production, though it does not return to its former desert or semidesert condition.

Soils of dry areas are formed in major part by the work of the agents of mechanical disintegration and to only a lesser extent by chemical weathering, for which water is necessary if it is to be important as a process in soil formation. With application of irrigation water, the normal processes of mechanical weathering, characteristic in dry areas, are interrupted and chemical weathering becomes active. This change in the processes which form the soil produces change in the soil itself. In the Salt River Irrigation Project in Arizona, for example, a survey made in 1899 showed that only 21 per cent of the soils were clays or clay loams, but a second survey in 1927 disclosed an increase of such soils to 82 per cent of all. Thus in 28 years the heavy, or fine-textured soils, increased nearly 400 per cent as a result of the breaking down of the arkose or desert sands resulting from mechanical weathering during the period prior to application of the highly saline water used in irrigation. This change in the character of the soils makes them harder to bring under production. Water is not absorbed readily, leading to use of an excess at additional cost. This causes both increased soil salinity and more rapid chemical weathering, both of which are objectionable.

From the foregoing consideration it is apparent that, though application of water may "make the desert bloom," the visibly attractive cultural landscapes of irrigated areas, which appear to indicate an improvement of conditions, may in reality only tend to conceal the fact that the net results of irrigation have not been beneficial. This may be because of inadequate markets or marketing facilities, but it frequently results from changes in the physical environment produced by irrigation practices: (1) increase of soil salinity; (2) the formation of alkali spots; (3) waterlogging; and (4) change in soil character. Whether the total of all change is for the better or the worse varies from project to project, and even within each project. It is by no means certain, however, though advocates of the extension of irrigation urge it as a fact, that the environmental changes produced by irrigation are in their aggregate always, or even generally, beneficial and commensurate with their costs, especially in the United States.

As with drainage, each project should be judged on its own merits; no general statement as to the desirability of irrigation applies to all. When the cost is not so excessively high as to levy too great a tax on the land benefited; when the land passes into use; and when profitable crops can be grown and marketed to advantage, irrigation pays. By contrast, irrigation is not warranted where high costs for water and inaccessibility to markets eliminate the possibility of profitable agricultural production. Under such handicaps, the limited opportunity presented does not tempt settlement, which imposes a still heavier tax on those who do occupy the land. Detailed studies of various irrigation projects indicate that some have been undertaken to advantage; others should never have been constructed. When successful, the environment has been modified to advantage; when unsuccessful, the reverse has been the case.

QUESTIONS AND EXERCISES

1. What fraction of the earth's land surface is grassland? What fraction of that of the United States? How does the areal extent of the world's grasslands compare with that of Africa? Of North America? How does the areal extent of the grasslands of the United States compare with that of your home state?
2. Under what general climatic conditions do most grasslands develop? What grasslands in the United States afford an exception to this general rule? To what are such grasslands probably a response?
3. Are the grasslands of all latitudes alike in appearance and in the opportunity they present to

man? If not, how and in what respects do they differ? How do the better watered grasslands of the United States differ from those of the Great Plains? To what use are the better watered grasslands of the United States best adapted? Those of the Great Plains?

4. Name the principal animals composing the fauna of the grasslands of the United States. How and why has overgrazing of the drier grasslands of the United States been disastrous? How has the fauna of the grasslands of the United States changed since white occupation?
5. Name some extractive industries other than mining. In what fundamental respect do the extractive industries differ from most of the other economic activities of man?
6. How does mining affect both the natural and cultural landscapes? Are such changes confined to the areas where the mines are located, or are they more widespread in their effects? Why? Illustrate by examples, from your home state if possible.
7. What is meant by "conservation of natural resources"? Why is such conservation highly desirable? How does unwise taxation interfere with conservation? Outline a plan for the wise and effective use of our mineral resources.
8. Of what type and size were the first irrigation projects in the United States? Why has recent development of irrigation projects in this country been largely by the government?
9. In what part of the United States are most of the important irrigation projects located? Why? Why is irrigation employed in the Lower Mississippi Valley, in areas with normally ample rainfall? What crop is grown on these projects?
10. What are some of the detrimental effects of irrigation? What is an alkali spot? How is it formed? How does irrigation sometimes alter the character of soils? Is this change advantageous or objectionable? Why?
11. Is irrigation practiced in your home state? If so, where and why? What crops are grown on such projects? What are the markets for these crops? Is this a handicap? Why?
12. What are some of the advantages enjoyed by the farmer in irrigated districts? What are some of the handicaps from which he suffers? Under what conditions is irrigation desirable?

SELECTED REFERENCES

Parkins, A. E., and Whitaker, J. R., *Our Natural Resources and Their Conservation*, John Wiley and Sons, Inc., New York, 1939, Chaps. VI, VII, XVI, XVII.

The chapters listed, written by different authors, afford a somewhat more extended consideration of the topics treated in this chapter of your text: the problems of the grasslands; the utilization of our arid and semiarid lands; and our mineral resources, including the mineral fuels.

Van Hise, C. R., *The Conservation of Natural Resources in the United States*, The Macmillan Company, New York, 1918, pp. 15–103 and 185–207.

The pages of this standard text on conservation cited discuss the problems associated with the exploitation of our mineral resources and the irrigation of our semiarid and arid lands, to increase their agricultural productivity. Though published some years ago, the discussion of principles included will prove of value.

Chapter Ten

THE CHANGING ENVIRONMENT: HUMAN AGENCIES PRODUCING CHANGE—AGRICULTURE

Importance of Agriculture as an Agency Producing Environmental Change. Of all the economic activities of man based on direct utilization of the assets of the physical environment, probably none alters the natural landscape more fundamentally than agricultural use of the land. In forested areas, it is seldom that lumbering operations alone destroy much more than the merchantable timber. Therefore the cutover land is ordinarily left with a tree cover after the lumberman has gone, and most of the traces of his activities disappear within a few years. Even where fires accompany or follow cutting, growth of some sort soon establishes itself. Thus, within a relatively short period of time, the burned-over area is recaptured by vegetation and, eventually, by some type of forest. Though this will probably be composed of less valuable species than those making up the original stand, it serves to conceal the occasional blackened stubs left by fires. Similarly, grazing, though often practiced unwisely in an attempt to extract the maximum from the pasturage in the shortest period of time, and without consideration of the future, seldom if ever destroys the grass cover completely, though altering its character and composition by changing the predominant species. Even for the most depleted of ranges, it is probable that a short period of rest would restore much of the former carrying power. The extractive industries such as mining normally affect only subsurface conditions, and, except in combination with associated activities, rarely produce permanent, observable surface effects. It is true that forest depletion, fouling of streams, and accumulation of mine wastes frequently accompany underground mining operations. Within a relatively short time after exhaustion of the mineral resource exploited, however, these unattractive evidences of human activity disappear with the elimination of sources of contamination, or they are masked by the growth of vegetation.

Drainage, usually accompanying agricultural use of the land, probably produces a greater permanent change in the natural landscape than does any other of the human agencies which have so far been considered, but the alteration is often largely the result of cultivation and crop production. Irrigation similarly causes fundamental changes in the appearance of an area. As with drainage, irrigation is normally for the purpose of making agricultural production possible or for increasing crop yields. Therefore the observable alteration of the landscape after irrigation results from the practices of agriculture rather than directly from the water made available.

In those areas where drainage and irrigation are an aid to use of the land for growing crops, changes in the environment are marked if agricultural invasion occurs; and the same is true wherever agriculture is practiced, either with or without drainage, irrigation, or special techniques in cultivation. The farmer clears the land if it is in timber, thus destroying the forest; he turns the sod wrong side up, thereby eliminating the native grasses. In this manner, the native vegetation and much of the native animal life disappear, to be replaced by cultivated crops, planted trees, and imported domestic animals. This displacement of the native vegetation and animal life may also be accompanied by the introduction of objectionable species of plants or "weeds"; prejudicial animals such as rabbits; harmful birds like the English sparrow; insect pests; and plant diseases. Under the changed conditions following human occupation, these

thrive at the expense of the remaining native life, cultivated crops, domestic animals, and man himself.

Soil Erosion. Some of the results of agricultural use of the land are beneficial; others are detrimental. Among those which work to man's disadvantage is accelerated erosion. With the disappearance of the former cover of native vegetation which held the soil in place and the substitution of a scattered stand of a crop such as corn in its stead, the water which falls as rain runs off more rapidly and completely than it did, carrying down the slope a load of soil in suspension. Not only do absence of vegetation cover and exposure of bare soil facilitate runoff, but, in many instances, unwise agricultural practices also aid in making runoff more rapid. For example, if the furrows left by plowing parallel the slope, as they frequently do, the running water finds a ready-made channel down which to flow and transport its load of suspended sediment.

The process of soil removal by either running water or wind is known as "soil erosion." As the term is commonly used today, it refers to "accelerated erosion" resulting from man's activities rather than to the slow removal of soil which occurs where man has not modified natural conditions. In the better watered areas of the United States, erosion by running water is more important; in the drier western states, wind erosion becomes sufficiently widespread in its effects to be significant, as is evidenced by the popular designation of part of that area as the "Dust Bowl."

Erosion by running water may be either one of two general types: (1) sheet erosion; or (2) gullying. The first occurs where runoff from the land surface is without undue concentration in definite channels, but is spread more or less uniformly in depth over the surface. Where this takes place, it results in the removal of a layer, or sheet, of topsoil of approximately equal thickness from the area affected; therefore the term "sheet erosion" to describe the type. Such erosion occurs on relatively flat slopes and in the most desirable agricultural areas. It is very serious,

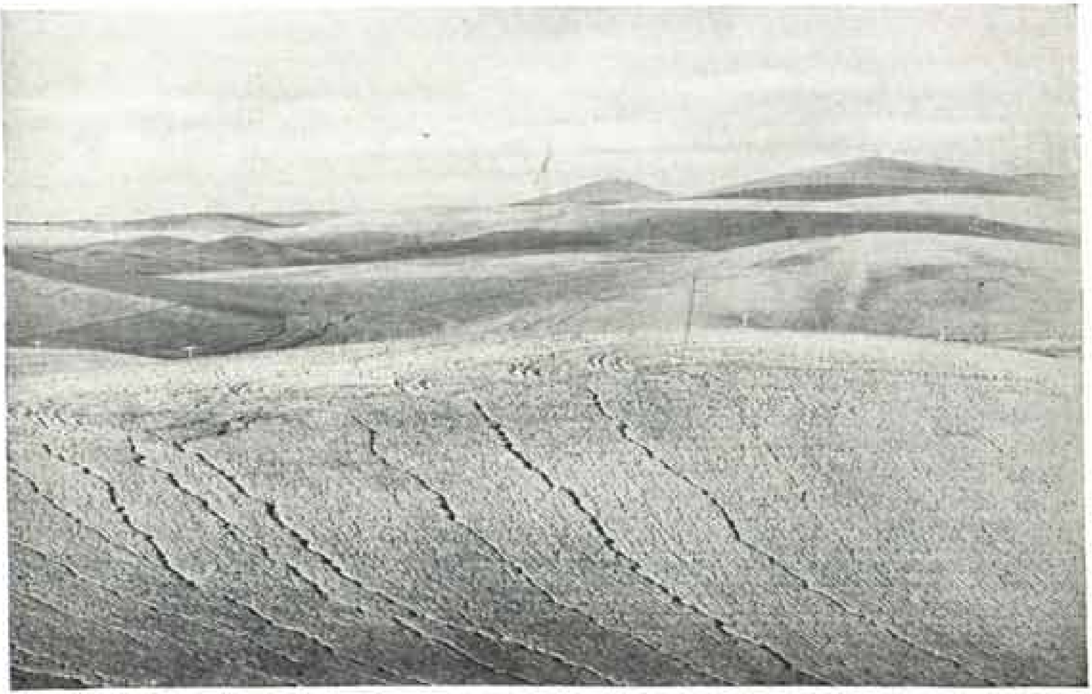


Fig. 63. Sheet erosion on Palouse silt loam, Latah County, near Moscow, Idaho. Summer-fallowed in 1933 and left unprotected during the following winter, the land lost at least 50 tons of soil from each acre. Not only has this land suffered from sheet erosion, but incipient gullies are developing where runoff has been more concentrated. (Courtesy of the U. S. Soil Conservation Service.)

FIG. 64. A field from which corn has been harvested, Fillmore County, southeastern Minnesota. This is in the Driftless or non-glaciated area where soil erosion is rather widespread and important. This shows how cultivation of corn up and down a 25 per cent slope causes the initiation of gullying. When rain falls, the water which runs off the field follows the depressions made by cultivation, deepening them and in time causing the development of serious gullying. (Courtesy of the U. S. Soil Conservation Service.)

FIG. 65. Gully development by headward erosion, 3 miles south of Moulton, Lavaca County, southeastern Texas. As water flows from the cornfield into the head of the gully, erosion occurs, and the gully increases in length. This process by which the gully advances up the slope is known as headward erosion, because it occurs at the head, or beginning of the gully—accompanying this retreat up the slope, additional tributary gullies develop. Unless checked, this process will destroy the entire field. (Courtesy of the U. S. Soil Conservation Service.)

for, though not always obvious and never spectacular, it affects the best land, the productivity of which it is important to maintain, as well as in many cases being the forerunner of gullying.

Gullying, by contrast with sheet erosion, is always apparent and often startling in its effects. Therefore it attracts widespread attention, though generally affecting areas of lesser agricultural desirability than those where sheet erosion is important. Where erosion takes the form of gullying, there is a distinct concentration of runoff in definite channels, the gullies, which deepen and widen very rapidly, as well as retreat up the slope by the process known as "headward erosion." As they increase in length, they also develop tributaries which grow in the same manner as the main gully. When gullies obtain a foothold in a field, it is often only a matter of a few years before it is ruined for cultivation unless steps are taken to prevent their growth.

Though soil erosion is widespread in the United States, and though it has produced much detrimental environmental change, it is ordinarily not serious in the glaciated areas, and the same is true in many of the western states. In the southeastern states, however, it is alarmingly prevalent. In many parts of this area it is possible to drive all day without at any time being out of sight of cultivated fields damaged by erosion, with occasional fields affected to the extent that they will probably never again be brought under the plow.

In these southeastern states precipitation is heavy, distributed throughout the year, and generally in the form of rain. This often falls in showers of considerable intensity on ground which is seldom frozen and never to great depths nor for extended periods of time. Under these

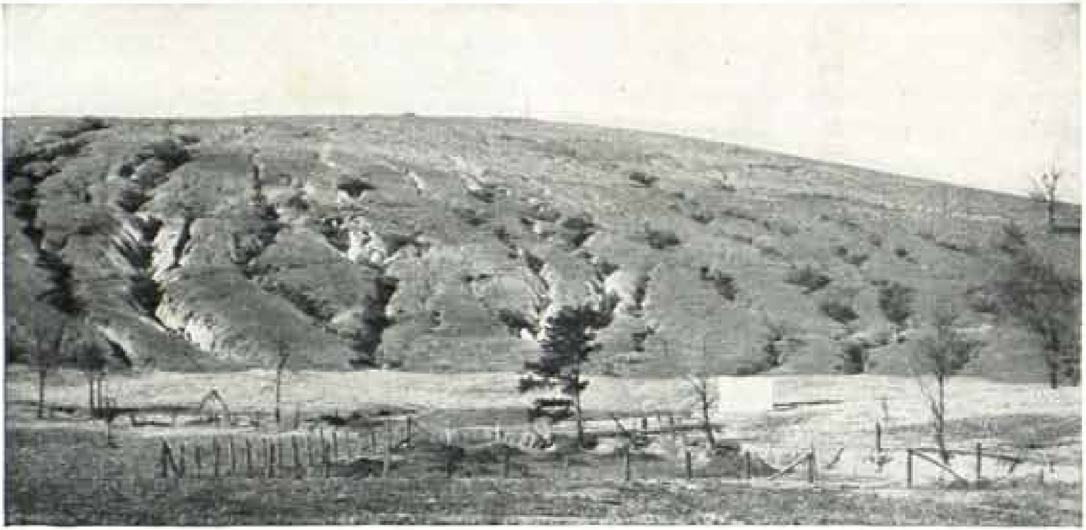


FIG. 66. Gullies deepening, widening, and retreating by headward erosion up a slope in Floyd County, northwestern Georgia, near Lindale. The field has already been ruined for all use except as it affords some poor pasture. (Courtesy of the U. S. Soil Conservation Service.)

conditions, important erosion continues throughout the year. Erosion is likewise facilitated by the fact that much of the country is hilly and many of the soils are hard, impervious clays which do not absorb water readily, thereby increasing the percentage which runs off. Accompanying these conditions, all of which increase erosion, is the mature or well-developed drainage pattern of this nonglaciated area: many streams with large numbers of smaller tributaries. In some parts of the South they are so numerous that a creek or "branch," which carries water only after rains, is crossed every few hundred feet in traveling across country. This multiplicity of channels, in

FIG. 67. The results of gullying in Lafayette County, northern Mississippi. Most of the land is unfit for cultivation and the small remnant still in crops will soon pass out of use under the prevalent practice of straight row cultivation, without reference to topography. (Courtesy of the U. S. Soil Conservation Service.)

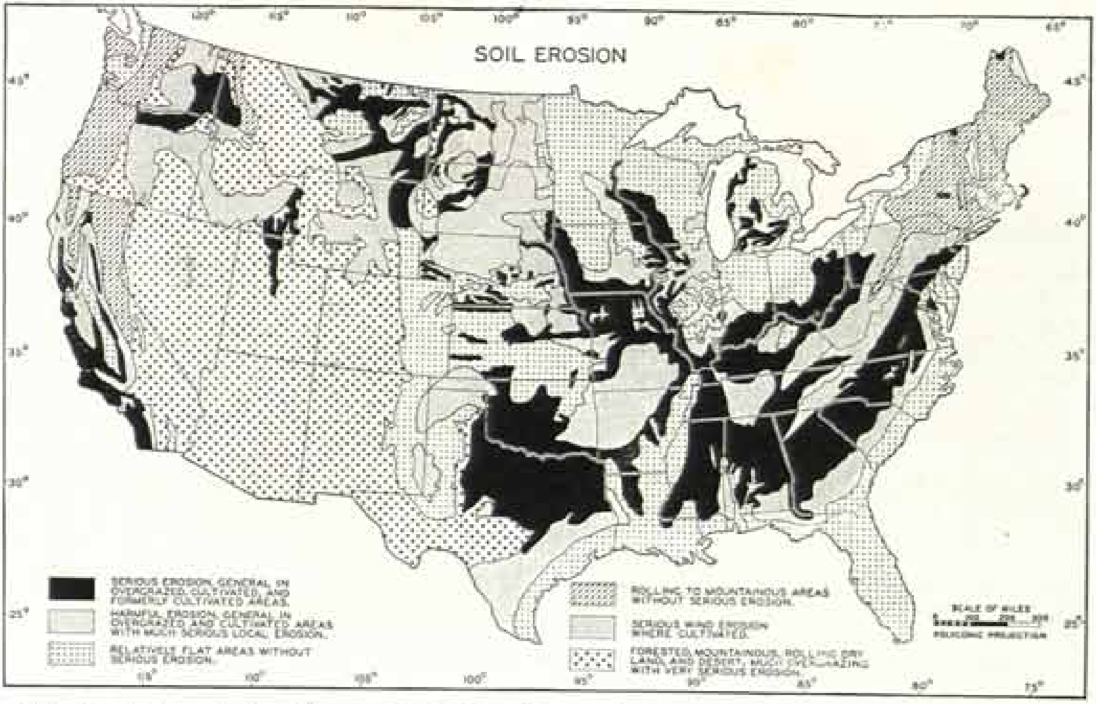


FIG. 68. Soil erosion is widespread in the United States, but the areas where it is serious are much more limited. Erosion by water is more general and important than that by wind, severe wind erosion affecting only a small percentage of the total area suffering in some degree from soil removal. (After H. H. Bennett, U. S. Soil Conservation Service.)

association with other favorable factors, makes runoff almost unbelievably rapid. A small creek or branch, dry before a rain, will often run bankfull during a heavy summer shower, only to become dry again within a few hours. Even the somewhat larger streams rise and subside with almost equal rapidity.

Added to these conditions of the natural environment which ensure rapid runoff are the contributing activities of man, particularly his agricultural use of the land. Deforested slopes, too steep to be cultivated advantageously, are plowed and put in crops; and, still worse, in crops such as corn, cotton, and tobacco, which, growing as they do without covering the ground completely, leave much of the soil bare and exposed to the attack of running water. When a field is not cropped, it remains without cover, except as it may grow up in weeds or sprouts. Crop rotation is not generally practiced, and sometimes plowing and cultivation are without reference to topography, so that furrows run up and down a hill rather than transversely across the slope. (See Fig. 67.) Thus runoff is increased and soil erosion is common.

In this part of the United States most of the soils are derived from residual material accumulated from disintegration of the underlying rock, which is often close to the surface. Therefore gullies may cut down to the solid rock and erosion, if active, may even strip moderate slopes of all soil cover. When this occurs, the solid rock forms the actual surface and the formerly cultivated field passes out of use permanently.

Wind Erosion. In addition to erosion by running water, wind also plays an important part in soil removal in the less well-watered portions of the United States, particularly west of the 100th meridian, in the Great Plains. Originally, the natural grassland cover of this area held the soil in place. But with overgrazing, and especially with subsequent "breaking" for agricultural use, generally for the production of wheat, the loosened soil, no longer held in place by grasses, pulverized by cultivation, and broken down in structure by a single-crop system, falls an easy

FIG. 69. Obion Creek, a stream about 100 feet wide, in southern Graves County, western Kentucky, 48 hours after a heavy shower. During and for a short time after the rain, the water stood at the depth shown on the piers of the bridge. At the time the picture was taken, two days later, the bed of the creek was dry, except for a few pools in the deeper depressions.

FIG. 70. Corn and tobacco on a steep slope in the Eden shale belt of western Anderson County, in the Bluegrass region of Kentucky. The underlying rock is a siliceous or sandy shale, weathering into a stiff yellow clay, which erodes badly on the steeper slopes. The use of fields with such steep slopes for the production of clean cultivation crops such as corn and tobacco is unwise, for under such use their life is very limited.

FIG. 71. Erosion has removed the soil completely; bare rock forms the actual surface of this field in the Eden shale belt of the Bluegrass region, in Anderson County, central Kentucky. The present condition results from unwise agricultural practices, with slope, soil, and climatic conditions favorable for rapid soil removal. In its present state, this field is unsuited even for reforestation; it has passed out of agricultural use for all time.

prey to strong winds in the drier years. In 1934, for example, the "dry blizzards" or dust storms removed millions of tons of fertile topsoil from the western dry-farming region and brought desolation and despair in their wake. This was the greatest disaster to overtake this region within the memory of man, either red or white. It was not alone a result of rainfall deficiency, but a result of such deficiency plus conditions induced by man's attempt to cultivate land at best only submarginal in agricultural opportunity on the basis of climatic conditions. It furnishes an excellent example of man's ineptitude and of his failure to use an area effectively.

Losses from Soil Erosion. The losses from soil erosion in the United States, both direct and indirect, are so enormous as to be almost past belief. Though the total extent of the badly eroded areas is not so great in recently occupied regions as in those of older settlement, the damage is widespread, extending from the Atlantic seaboard to the Pacific coast, and from the Canadian boundary to the Rio Grande and the Gulf of Mexico. Erosion affects in greater or lesser degree all areas where man has removed the native vegetation cover, either grassland or forest. It is a very serious problem in the grazing areas of the West as well as in the better watered agricultural regions of the East; no area in human use escapes completely.

Hugh H. Bennett, who has given a lifetime of study to the problem, estimates that more than 75 per cent of the deforested, grazed, and cultivated area of the United States has been affected adversely by erosion. From this area, 3,000,000,000 tons of earth, mostly topsoil, are removed each year. This material is in part carried directly into our rivers, lakes, and bounding bodies of salt water; in part it is deposited as a veneer on the flat land at the bottom of

FIG. 72. An approaching dust storm in Prowers County, southeastern Colorado, March 21, 1937. During this storm, which occurred late in the afternoon and lasted nearly 3 hours, the wind velocity was approximately 30 miles per hour. During severe storms, visibility is practically zero, even at noon. Dust sifts into the houses, interferes with traffic, and worst of all, the top soil of the farms is blown away. (Courtesy of the U. S. Soil Conservation Service.)

FIG. 73. Wind erosion in Beadle County, eastern South Dakota, September 22, 1936. The drifted soil is nearly 4 feet in depth. This was formerly a prosperous farm, with good buildings, but it is now abandoned. This has caused a loss of the money invested in improvements, as well as the amount invested in the land. (Courtesy of the U. S. Soil Conservation Service.)

FIG. 74. Strip cropping, Winona County, southeastern Minnesota, in the Driftless area, November 4, 1936. The dark strips are newly plowed, with alfalfa between them. The contrast in the amount of erosion on the denuded slope at the left and the tree-covered slope at the right shows the effect of forest cover in retarding runoff. (Courtesy of the U. S. Soil Conservation Service.)

the steeper slopes. When this deposit is a thick layer of sterile sand or other coarse material, the fields on which the deposition occurs are ruined for further production, so that both the slopes and the flat land pass out of use.

In addition to this direct loss of topsoil, water as it runs off yearly carries with it an invisible load of dissolved mineral materials used by plants, estimated by the United States Bureau of Chemistry and Soils to have a value of $9,500,000,000. This is approximately sixteen times the amount of money spent annually in the United States for the purchase of commercial fertilizers. This loss of mineral materials essential for plant growth decreases crop yields and deprives our farmers of millions of dollars of income each year. As erosion becomes more serious, abandonment of the land is forced by decreased productivity. This destroys not only the original investment in the land but also that in buildings, fences, and other improvements. Thus the total monetary loss increases materially, and may exceed more than twice the actual value of the land in some cases.

Not only farmers, but others as well, suffer direct losses from soil erosion. The soil which washes from the fields is in considerable part deposited in our streams, which decreases their navigability. When navigability is lessened, our waterways are usable only with additional expense and, even then, less effectively. Silt borne by the running water also settles behind dams constructed to store water for power development or irrigation, decreasing storage capacity and increasing costs of water for either use, as well as eliminating substantial investments made on the assumption of a continuously sufficient supply of water.

Prevention of Soil Erosion. It might appear that self-interest alone would induce those aware of the dangers of soil erosion to take the steps necessary to check its ravages. However, many farmers believe that the costs of its prevention are prohibitive. Further, the temptation to sacrifice the future for an immediately larger profit has, in the past, been so overpowering that it has led to neglect of the necessary precautions and an exploitation of our soils matched in few if any places in the civilized world. It might even seem that the staggering losses from soil erosion would enlist popular support for legislation making it illegal to dump farms into our waterways, even

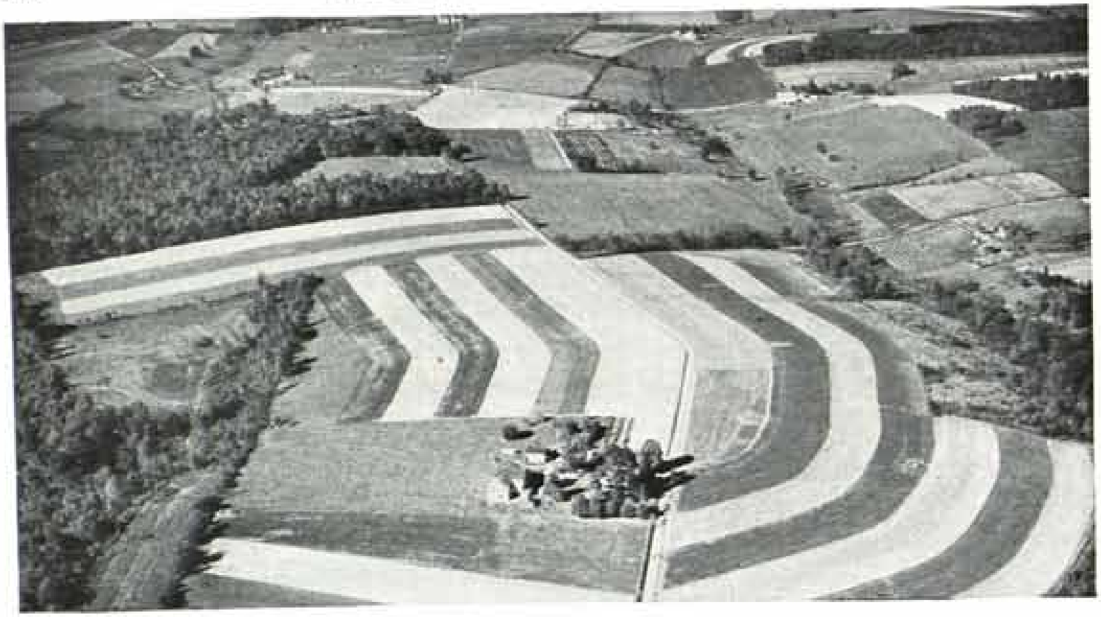


FIG. 75. Strip cropping and contour plowing in Lancaster County, Pennsylvania, October 18, 1939. In this old, highly developed, and productive agricultural area of southeastern Pennsylvania, though most of the fields under cultivation have gentle slopes, soil conservation practices are beneficial in preventing sheet erosion. It will be noted, however, that such practices are not followed on all farms. (Courtesy of the U. S. Soil Conservation Service.)

gradually, as is the case where running water is the transporting agency, but here again the public has been, and still is, largely apathetic because of failure on the part of most individuals to realize that erosion causes a personal loss. Curiously, such present interest as exists is in considerable part because of political expediency.

As a result of our past policy, we are today faced with a critical situation and must make a choice. We have already lost approximately half of the original soil cover; what remains is being removed at a rapid rate. Either erosion goes on unchecked, and we lose so much more of our fertile farm land that production will not suffice to satisfy demands; or it must be controlled. If we choose the program of control, this will, as by-products, ensure increased navigability of our rivers, lessen the likelihood of extremely high flood stages in our streams, and produce other benefits of related character.

As a necessary preliminary to intelligent action for control of soil erosion, our lands should be classified according to their most effective use. Such classification will reveal areas with steep slopes, deficient rainfall, and other conditions which unfit them for plowland. These should be withdrawn from agricultural use and reforested, or used for regulated grazing, dependent on their characteristics.

The remaining area, which may be devoted to growing crops, should be "repaired" where necessary by the elimination of washes and gullies. This may be done by building dams of some sort, brush if necessary, which will cause filling and gradual extinction of the gullies. Thereafter, gullying should be prevented by intelligent use of the land. Strip cropping, or the growing of alternate, parallel strips of soil-holding crops, such as grasses or small grains, and clean cultivation crops, such as corn or tobacco, at right angles to, or across the slope, will do much to retard runoff and prevent objectionable slope wash. In some cases, modified terracing, or the throwing up of ridges across the slope, is highly effective. Basin furrowing, or the excavation of thousands of shallow depressions by machines designed for that purpose, surface irregularities which hold the water and allow it to sink into the ground, has also been found to be useful under certain conditions. All these methods

FIG. 76. Fresh terraces, Houston County, southeastern Minnesota, in the hilly Driftless on nonglaciated area. By throwing up several furrows, forming terraces or obstructions across the slope, runoff is checked and the soil is held in place. (Courtesy of the U. S. Soil Conservation Service.)

are mechanical means of arresting runoff and allowing the soil to absorb water, so that it will not cause erosion but will benefit the crops later in the season.

In addition to more intelligent plowing and planting it is desirable that agricultural practices be followed which will improve the physical characteristics of the soil so that it will absorb, not shed water, which latter causes soil erosion. These practices would involve less "soil mining," that is, sale of the soil minerals used by plants in the form of agricultural products, and a return to the land of an equivalent of those removed by crops. This can be accomplished in a variety of ways, with crop rotation, increase in the animal industries, and application of commercial fertilizers, among the list of possible methods.

Inasmuch as the problem of serious soil erosion confronts us today, it should be met now, not tomorrow, for each day of delay increases its seriousness and the difficulty of its solution. To counteract the undesirable effects of soil erosion on environmental conditions, plans for its prevention should be formulated and put into operation in the immediate future. The success or failure achieved in the carrying out of such plans must depend on the degree of cooperation secured. Since everyone is affected, both directly and indirectly, it is vital that all realize their interest and take steps to protect it.

Soil Erosion in Other Parts of the World. The problem of soil erosion is not new, nor is it confined to the United States. It is almost as old as agriculture, for excessive removal of soil began with the earliest productive use of the land without methods adapted to slope and soil conditions. Its adverse effects were felt in ancient Mesopotamia. In Palestine, erosion, which began at least as early as Biblical times, has continued until today practically all soil has been removed from many formerly forested slopes. The same is true in Greece. That it presented a problem in Roman agriculture is indicated by the writings of Pliny during the first century after Christ, for he advised farmers to practice contour plowing, or to plow across rather than up and down the slope. This problem was, and still is, common in all Mediterranean agricultural areas, where rainfall is light, slopes are sometimes steep, forests sparse, and other conditions as well are favorable for rapid runoff.

When agriculture advanced into the better watered regions of northwestern Europe, the problem of soil erosion accompanied its invasion of those areas. In places in England, for example, evidences of Roman cultivation 5 feet below the present surface indicate the extent to which wash and deposition have occurred since the days of Roman occupation. Even today, many old, eroded fields, abandoned after the Saxon conquest, are still uncultivated. The problem of soil erosion was intensified during the Medieval period by the fact that the tenants, not holding their land permanently, had inadequate incen-

FIG. 77. Basin furrowing near Humboldt, Nebraska, Feb. 10, 1937. The curved furrows, which run at the same level or follow the contour, are divided into basins, each 8 feet in length. This decreases the probability of runoff along the furrow. With melting of the snow cover, the water is held in the basins and absorbed gradually, except for the part which evaporates. As a result, there is almost no runoff on this field and erosion is prevented. (Courtesy of the U. S. Soil Conservation Service.)

tive to practice careful tillage, and that the farm animals were pastured on commons, so that fertilizer was lacking for use on cultivated fields. The low crop yields, inevitable under these conditions, and the steady increase of population at that time, led many to believe the productive capacity of the land would eventually become insufficient to feed all.

In the densely populated agrarian areas of Asia, soil erosion also assumes serious proportions. In some places, indeed, its ravages are at least as great if not greater than in the most seriously affected parts of our own country. North China, for example, where both wind and water conspire in association with man's activities to produce some of the worst cases of soil erosion in the world, has lost so much "good earth" that the country is often desertlike in appearance. Swollen by rapid runoff, caused in part by denuded slopes, the floods of the Hwang Ho bring desolation and famine to this densely populated part of the earth's land surface with monotonous regularity. So important in the life of the Chinese are these regularly recurring catastrophes that the Hwang or "Yellow River," so-called because of its burden of silt, is sometimes known as the "River of Sorrows."

Even Japan does not escape, for recent removal of forest to supply the needs of industry has developed an erosion problem of such proportions that it has become necessary to reforest many of the steeper slopes in order to regulate runoff, and thus ensure a steady supply of irrigation water, the lifeblood of Japanese agriculture, for the cultivated fields. In the Eastern Hemisphere, also, both Australia and South Africa, upon which industrialized Great Britain depends for much of her food supply, have likewise been badly ravaged by soil erosion.

In the Western Hemisphere outside of the United States, soil erosion is particularly serious in Latin America. To the south of us, Mexico has suffered so severely that, in some areas, the fields are either gullied or perched between gullies which encroach and threaten to devour them. Elsewhere, equally prevalent and serious sheet erosion is indicated by numerous exposures of solid rock. Farther to the south, in South America, the formerly productive area of the Inca Empire is slowly wasting away. Today, when seen from the air, its pockmarked surface often suggests afflication by a horrible skin disease. This grim list of areas suffering from serious soil erosion could be extended to include many other countries of the Western Hemisphere, southern and eastern Europe, and densely populated parts of Asia.

That "all flesh is grass" is as true today as in the past, for the food man eats comes from the soil. Even though we may some day substitute pills for bread and meat, we shall still be dependent on the surface layers of the earth. Yet, in many parts of the world, vast tracts of formerly productive land have been permitted to become near-deserts, with their present inhabitants living under slum conditions. When food shortages develop as a result of wartime dislocations, even governments may err in encouraging

or even exerting pressure to induce an intensified use of the land which speeds its destruction.

Slowly but surely our soils are disappearing; we have made but slight progress in checking the process. Yet both population and needs continue to increase. Despite these facts, we still overgraze much of our grassland; we persist in using our rivers as sumps; we are getting thirstier and thirstier. Further, we continue to depend too much on the rule-of-thumb methods of the "practical or dirt farmer" rather than upon the advice of the skilled land-use technician. Inevitably, we already pay the penalty in decreased per acre yields and, unless we mend our ways, the future will be dismal indeed, for certain disaster will over take us.

QUESTIONS AND EXERCISES

1. Compare the effects of agriculture in altering the natural environment with those produced by man's other economic activities based on direct utilization of the assets of the physical environment.
2. Why does destruction of the native vegetation cover and the substitution of cultivated crops tend to increase rapidity of runoff and soil erosion?
3. What are the two agencies which produce soil erosion? What are the two types produced by running water? Which one of the two types produced by running water is more important and serious in our best agricultural areas? Why? Why does gullying ordinarily attract more attention than sheet erosion?
4. In what parts of the United States is soil erosion most serious? Why? In what parts of the United States is soil erosion relatively unimportant? Why? What fraction of the United States has been affected adversely by soil erosion?
5. Why is runoff so rapid in the South? How does the agricultural system and agricultural practice in the South tend to increase soil erosion?
6. In what parts of the United States is wind erosion important in removing soil? What uses of the land in this part of the country have caused a great increase in soil erosion? Is the importance of wind erosion increasing or decreasing? Why?
7. Why has soil erosion increased in the drier parts of the United States with increase of settlement, and particularly with the introduction of dry farming?
8. How great is the financial loss from soil erosion in the United States? Why may the financial loss from accelerated erosion exceed the value of the land?
9. How does soil erosion affect the use of our rivers? What uses are affected? State the detrimental effects of accelerated erosion on each use.
10. How may objectionable soil erosion be checked? What is meant by contour plowing? By strip cropping? By modified terracing? By basin furrowing? How does each assist in checking objectionable erosion?
11. Is soil erosion confined to the United States? If not, when did it begin in other parts of the world? How do we know this? In what parts of Europe is soil erosion most serious? Why? Is soil erosion important in Latin America? Where?
12. Does serious soil erosion occur in Oriental areas? Where? How serious is the problem there? In what part of China is soil erosion most serious? Why? Why is the Hwang Ho sometimes known as the "Yellow River"? The "River of Sorrows"?

SELECTED REFERENCES

Bennett, H. H., *Soil Conservation*, McGraw-Hill Book Company, Inc., New York, 1939, Chaps. I-IV.

The title of this book indicates the subject matter treated. The topics covered in the chapters suggested for reading are: the problem in the United States; erosion and civilization; results of erosion; and principles, processes, and types of erosion, one chapter being devoted to each. This reference affords the most recent and comprehensive treatment of soil erosion available in our language.

Parkins, E. A., and Whitaker, J. R., *Our Natural Resources and Their Conservation*, John Wiley and Sons, Inc., New York, 1939, Chaps. IV and VI.

The chapters suggested for reading in this useful reference are concerned with soil erosion and its prevention; and the utilization and conservation of our arid and semiarid lands. Treatment of these topics is both interesting and relatively comprehensive in this well organized and timely consideration of effective use of our natural resources.

PART FOUR. ELEMENTS OF THE PHYSICAL OR NATURAL ENVIRONMENT

Chapter Eleven

CLIMATIC ELEMENTS: SUNSHINE AND TEMPERATURE

Population and Environment. Population is normally above average density in areas of natural opportunity, especially where initial attraction has been enhanced by human activities; sparse where original opportunity was limited, and time and progress have not altered possibilities materially. Initial attraction resulted from different *combinations* of climate, fauna, flora, topography, and other environmental factors, which afforded varying degrees of opportunity and in a degree variable with the stage of development of man. Wherever he has intruded his activities, subsequent change has not only modified the original value of individual factors of the environment, but likewise their *interrelationships* and the *combined* value of all. In the following discussion of the limiting effects of environment, however, individual factors will be considered separately for practical reasons, despite the fact they normally operate in combination, not singly.

Climate and Life Forms. Climate affects the range of both elements of the native vegetation and cultivated crops, plant structure and habits, and the luxuriance of plant growth. Where sufficiently repressive, even deserts may result: either the dry deserts of the lower latitudes or those of snow and ice of the polar regions. Animal life is affected similarly with respect to range of species, appearance and habits, and abundance. These effects on plants and animals influence man's distribution, activities, and comfort, both directly and indirectly, in a degree varying with his stage of development. The climatic factors producing these results are sunlight, temperature, moisture conditions, and winds, particularly as the last affects precipitation.

Sunlight and Its Function. Sunlight is necessary for the functioning of life processes of all green plants for, without it, they are unable to utilize the raw materials, water and carbon dioxide, to make sugar, which is later transformed into starch and other plant foods. The tabulation below shows the relation of sunlight to this

Factory: Green plant
Raw Materials: Carbon dioxide and water
Power: Sunlight
Manufactured product: Sugar
By-product: Oxygen

process of photosynthesis, or "manufacture" of sugar by plants. The plant functions somewhat like a factory, using carbon dioxide obtained from the air and water from the soil to produce sugar, with surplus oxygen a by-product. This process takes place largely in the leaves. Power is supplied by sunlight; therefore the plant factory "operates" or produces sugar only during the daytime and most rapidly during that part of the daytime when the sun is shining brightly.

This sugar or other plant food is used by the plant to promote vegetative growth and for storage in seeds, which consist essentially of an embryo and a food supply, the latter to serve until leaf and root systems which draw upon the air and soil are perfected. If the sun does not shine brightly, little or no sugar is made; vegetative growth is checked; and seeds do not fill out properly. Different plants, it is true, vary in their light requirements, but the fact that many do not thrive and some may even die in the shade indicates that sunlight is necessary for their growth.

The seed, or its equivalent from the standpoint of reproducing the plant, is a device perfected to tide over a period unfavorable for growth because of low temperature or precipitation de-

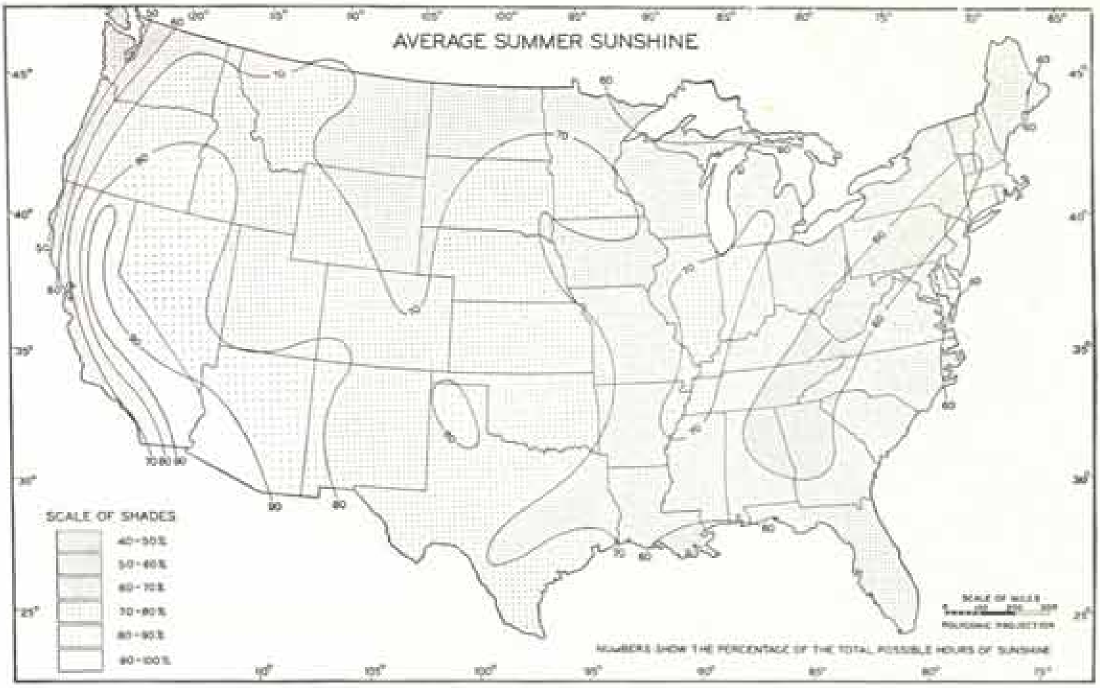


FIG. 78. This map shows the average percentage of the possible hours of sunshine for the United States during June, July, and August. For example, if the daylight period at Chicago on a given date during any one of these three months is 15 hours in length, there will be 70 per cent of 15 hours, or 10.5 hours, of sunshine there on that date. (After the Atlas of American Agriculture.)

ficiency. It is, therefore, a resting stage in the life history of the plant species. To perform its function, food must be stored in the "seed," where it will be available when conditions for growth are again favorable. Unless there is sufficient sunshine, however, this is impossible. For man, the seed or its equivalent affords a large part of his food supply. But, when it is cloudy, photosynthesis is checked and seeds do not fill out properly; crop yields are decreased; and man is affected adversely.

Sunlight and Agriculture. The percentage of the possible hours of sunshine affects agriculture in two ways: (1) by limiting the number of crops which can be grown profitably; and (2) by affecting the yields of crops grown. The first of these two effects follows from the fact that crops have different sunshine requirements. Unfortunately, those which can be grown to advantage in areas with much dark, cloudy weather are those which are less profitable, for example, hay and oats. Therefore the agricultural desirability of an area is decreased by a low percentage of the possible hours of sunshine. The second effect, that on yields, influences profits directly. Thus the amount of sunshine becomes an important factor in determining the relative agricultural desirability of areas.

Temperature Distribution. Air temperatures, which make human life possible on the earth's surface, result from insolation, or "exposure to the rays of the sun." Since the amount of heat received from the sun varies with both latitude and the season, temperatures differ from place to place and change from time to time in the same place. (For an explanation of the cause of this, see Chap. XLVIII.) They also differ at a given place during the day, principally because of variation in the verticality of the sun's rays; and likewise at a given time in the same latitude, for land both heats and cools more rapidly than water. Thus, when temperature distribution is plotted on a map by means of isotherms, lines so drawn that all points on each have the same temperature, the isotherms depart from their approximately east-west paths over the oceans and bend

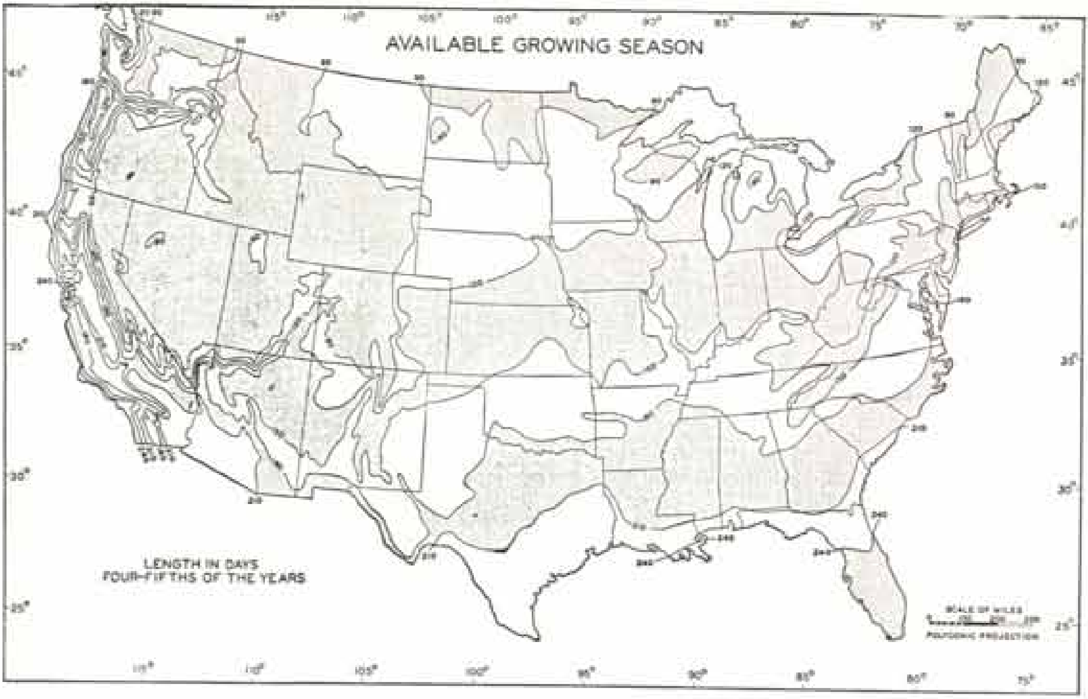


Fig. 79. The available frost-free season or the effective crop season, four years out of five. (After the Atlas of American Agriculture.)

either north or south over the land, often rather sharply. Further, isotherms over the oceans vary in location at different times of the year only within narrow limits, whereas seasonal temperature change over the land during the year causes them to shift north and south for considerable distances. This varied distribution of temperatures causes the earth's surface to differ in habitability from place to place.

Low Temperatures and Plants. When the temperature falls sufficiently, herbaceous plants are commonly killed, though the definite change which produces this result is apparently still in dispute among biologists. The exact temperature at which killing will occur varies with both the species of plant and the season, but, on the average, it is about 32°F., the freezing point of water. With some plants, however, it may be lower, and it likewise varies from time to time for a given plant species. During the summer, for example, a sudden drop of temperature to 32°F. is ordinarily more disastrous than the gradual lowering to the same point which occurs in the fall. Apparently the plant is able to make an adjustment to small and gradual temperature changes to 32°F., or even slightly below, but not to those which are both great and sudden. This fact is of significance in that it affects regional agricultural desirability.

Frost and the Frost-free Season. The period between the last killing frost in the spring and the first killing frost in the fall is known as the "frost-free" season. Its length is important in that it is one of the factors determining what crops can be grown to advantage in a given area. A short frost-free season is always a handicap, for only a few crops can be grown and matured in the time available; a long frost-free season is an advantage because it increases the number of crops, and particularly the number of profitable crops, which can be grown without undue risk of frost damage. Further, the greater diversity of crops possible tends to make agriculture more profitable.

In planning agricultural production for any given area, it is necessary to take into account not only the average length of the frost-free season, but the amount of departure from this average as well. In areas where this departure is frequent and great, the length of the available frost-free

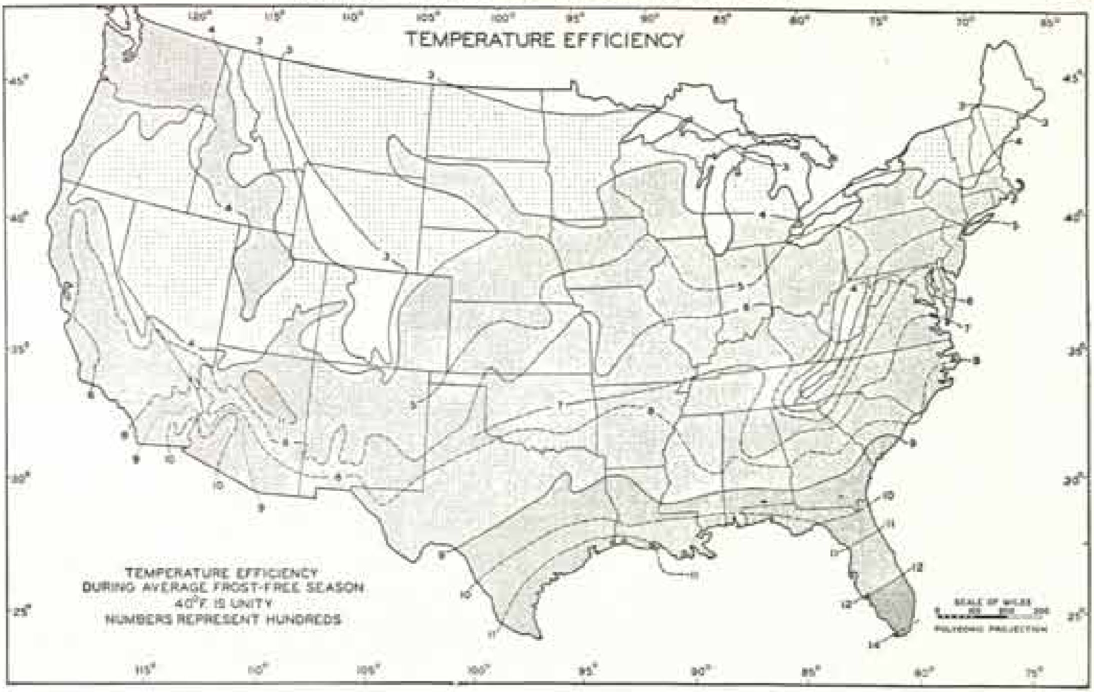


FIG. 80. Temperature efficiencies in the United States during the average frost-free season, on the assumption that plant growth stops at 40°F. On the map, the numbers showing temperature efficiencies represent hundreds. Therefore the temperature efficiency at Minneapolis would be 400; that at San Diego would be 800, or twice as great. (After Livingston and Shreve.)

season is decreased materially; in areas where the departure is slight and relatively infrequent, the effective and the average frost-free seasons are essentially the same. Therefore these latter areas are more desirable, other conditions being equally favorable. In determining the availability of any area for the production of a given crop, it is customary to consider the effective length of the frost-free season as its length in four-fifths or nine-tenths of the years rather than the average, which may misrepresent the practicable length greatly where departure from the average is considerable and frequent.

Temperature Efficiency. Though plants are not killed by low temperatures, except at freezing or below, plant growth stops considerably above 32°F., on the average at 40°F., with departures from that temperature varying with the plant species. At temperatures between 32°F. and 40°F., therefore, plants become dormant, or growth ceases. For this reason, the effectiveness of temperatures in promoting plant growth during the frost-free season varies with the number of days they rise above 40°F., and the amount of rise above that point. Thus two areas may have frost-free seasons of the same length, yet differ greatly in agricultural desirability because of differences in temperature efficiency.

Low Temperatures and Animals. Where winters are long and cold, some warm-blooded animals, such as bears and bats, and all cold-blooded animals like frogs, toads, and snakes, hibernate. They select some sheltered retreat and, becoming dormant almost to the point of death, breathe very slowly, sometimes not more than nine or ten times an hour. Thus they are able to live for months on the store of fat accumulated during the preceding summer and fall. Other animals which do not hibernate, as well as many birds, migrate with the changing seasons in order to escape low temperatures. Some of the birds of the Arctic, for example, shift to lower latitudes in the late fall and back to the Arctic in early spring. Others move south, even into the Southern Hemisphere, in our fall, and back again in our spring. Migration of the animals, for example those of the caribou, are for shorter distances. Among the animals which remain throughout the

year in an area characterized by great annual temperature range, many change their coats with the seasons. This is partly as a protection against enemies, but generally to afford protection against cold as well.

Low Temperatures and Man. There is no part of the earth's land surface which is uninhabited because of low winter temperatures, for man has learned how to cope with such unfavorable conditions. Therefore the length of summer and temperatures of the summer months are of greater importance in affecting the habitability of a region than temperatures of the cold months. Thus people live at Verkhoyansk, in Siberia, where the average January temperature is −58.2°F. and where the temperature has fallen as low as −93.6°F. By contrast, many areas in the Arctic with much higher winter temperatures are uninhabited because of too short and too cold summers. Even though some of these very cold areas are inhabited, their low temperatures multiply the problems of existence and constitute a serious handicap.

Low Temperatures and Soils. The effects of low temperatures on soils are in general beneficial. Mineral soils are formed in large part by the mechanical and chemical weathering of rock material. Freezing and accompanying expansion of water in the joint and bedding planes, or larger openings, and in the pore spaces between the mineral grains in the apparently solid rock, force the larger fragments apart and weaken the bonds holding the smaller grains together. This fragmentation, valuable in soil formation, also aids chemical weathering by increasing the surface exposed to attack, though not necessarily to an extent to compensate for the slowing down of such action by low temperatures. Alternate freezing and thawing also leave the soil loose, open, and porous, thereby improving conditions for plant growth. The farmer describes this loosening effect by saying that the ground "heaves" in the spring when the frost goes out, though heaving actually occurred at the time of freezing, when expansion occurred.

Most mineral soils contain a considerable percentage of organic material, derived from plant residues. It is this which imparts the black color so common in the soils of intermediate latitudes, where low temperatures check decay and decomposed plant remains are available for incorporation in the soil. The presence of this material is beneficial in a variety of ways which will be considered in a later chapter.

Low temperatures also check leaching or loss of soluble soil minerals which are used by plants. Where it is warm throughout the year and rainfall is abundant, movement of water in the soil and loss of these soluble minerals is continuous. On the other hand, where temperatures fall to freezing or below for long periods of time, the process is interrupted and the soluble minerals are retained for use by plants during their season of growth. Low temperatures also conserve soil moisture by decreasing evaporation, and they check erosion, which cannot occur when the ground is frozen and is decreased at other times by loosening of the soil as a result of frost action. Hence soil erosion is normally less severe in areas with long cold winters than in those regions where it is warm throughout the year, except as other factors favoring soil removal may offset the effects of low temperatures.

High Temperatures and Plants, Animals, Man, and Soils. With high temperatures throughout the year, plant growth will be luxuriant and there will be no resting period imposed by climate, if rainfall is ample and its distribution is favorable. Animals will neither hibernate nor migrate for, with constant high temperature and otherwise favorable conditions, such movement is not necessary. Nor will they change their coats if temperatures vary but slightly and other significant change is lacking. In view of the fact that it is not necessary to provide against a cold season, life is much simplified for both the animals and man in many respects.

On the basis of high temperatures alone, no part of the earth's land surface is uninhabitable or uninhabited. At Yuma, Arizona, temperatures have exceeded 100°F. in the heat of the day for 80 consecutive days, except for one; in Death Valley, California, a maximum temperature of 134°F. has been recorded; at Aziza, 25 miles south of Tripoli, one of 136.4°F., the highest day temperature of record, yet man can and does live in all these places.

Soils, however, are affected adversely in well-watered areas by continuously high temperatures. They tend to be hard and compact in the absence of loosening by frost action; they are lacking in organic material, for decay occurs throughout the year; and they are badly leached and highly oxidized. They are, therefore, less desirable on

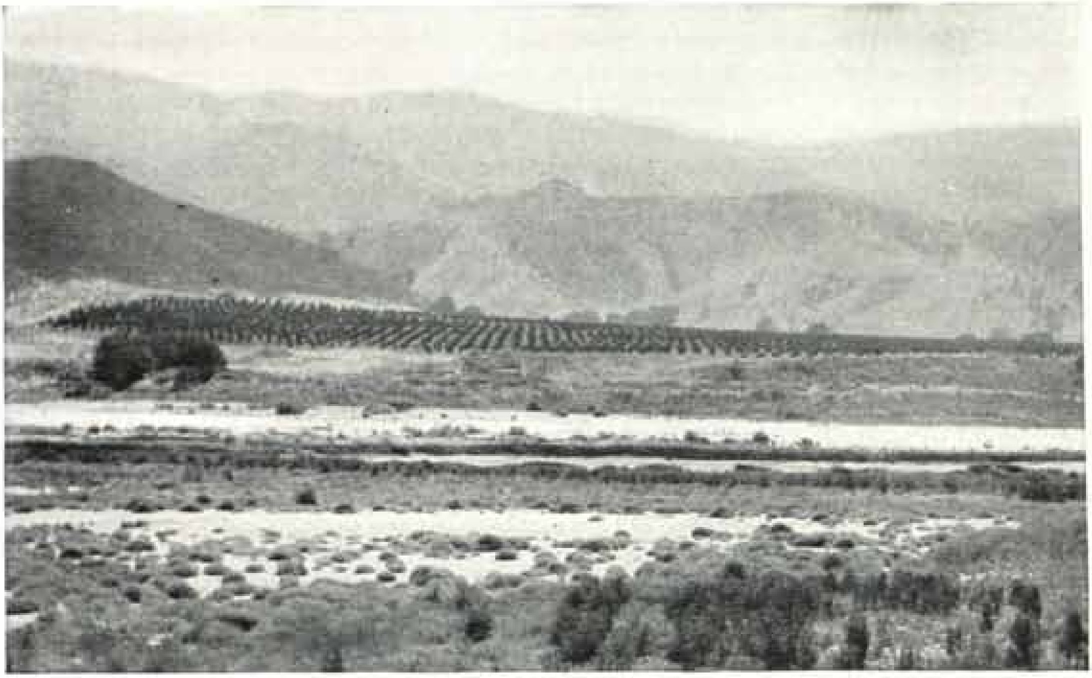


FIG. 81. A citrus orchard on an alluvial fan, a fan-shaped land form of material deposited by water, at the foot of the Coast Range in the background, in the valley of the Santa Clara River, eastern Ventura County, California. When temperatures fall, the air, as it cools, flows down the slope of the fan and accumulates in the depression near the river. There, frosts are too frequent to allow use of the land for orchards. Note the lower limit of planting on the fan, which marks the level below which the frost hazard becomes considerable

the average than the soils of intermediate latitudes, and the luxuriant vegetation they often support is a response to climate, not soil fertility.

Crops and Frost. Most crops of the higher latitudes are annuals, planted late enough in the spring so that frost danger is slight, or, if fall planted, they do not reach a stage of growth during which frosts are detrimental until the risk of killing frost is negligible. Harvest occurs in the summer or early enough in the fall so that ordinarily there is likewise no damage to the crop from frost at that season.

With garden crops particularly susceptible to frost damage, however, and with orchard and other fruit crops which are perennials, special precautions are often taken to minimize or prevent frost danger. These fall into two general classes: (1) choice of a location such as to eliminate, or at least decrease, the probability of frost; and (2) special measures for the prevention of frost occurrence.

There are two types of relatively frost-free locations suitable for commercial orchards, in addition to one in a latitude low enough so that frosts are either infrequent or unknown. The first of these is on a slope; the second is near a lake or body of fresh water of appreciable size. On slopes, frost danger is decreased by air drainage, which results from the fact that, as air cools, its weight per unit of volume increases. Therefore, as it cools, it flows down slopes and accumulates in depressions. Thus, during the night or any cold spell of the spring or fall when frosts threaten, the air which comes in contact with the orchards planted on slopes rarely drops to a temperature of 32°F., though heavy frosts may occur in the depressions into which the cold air drains. Frost protection is likewise afforded by lakes and other bodies of fresh water, because water both absorbs and loses heat slowly. In the spring, therefore, the lake waters, cooled during the preceding winter months, warm slowly, thereby keeping temperatures over the near-by land low. This retards blossoming of fruit trees until the danger of frost is past and thus prevents frost damage. In the fall, the lake waters retain their heat, pre-

venting low temperatures and frost near the shores. The lake, it will be noted, functions differently in the spring and fall in preventing frost damage. In the spring, it does not prevent frost, but retards blossoming, which prevents frost *damage*; in the fall, it prevents *frosts*.

Garden and Fruit Crops and Their Protection from Frost. In case frost impends, despite care in selection of the area of planting, it and its damage may sometimes be prevented by: (1) checking radiation or loss of heat; or (2) maintaining temperatures above freezing by heating the air. Radiation may be checked by a cover of some sort, which prevents loss of heat from the ground to an extent that freezing temperatures do not occur under the cover. Garden crops which bring in a high return per acre of land under cultivation may be protected with profit in this manner. A similar result may often be secured at much less expense by soaking the ground with water which, because of its slow loss of heat, may keep the soil warm enough so that temperatures in the surface layers of air will not drop to 32°F., and frost will not occur.

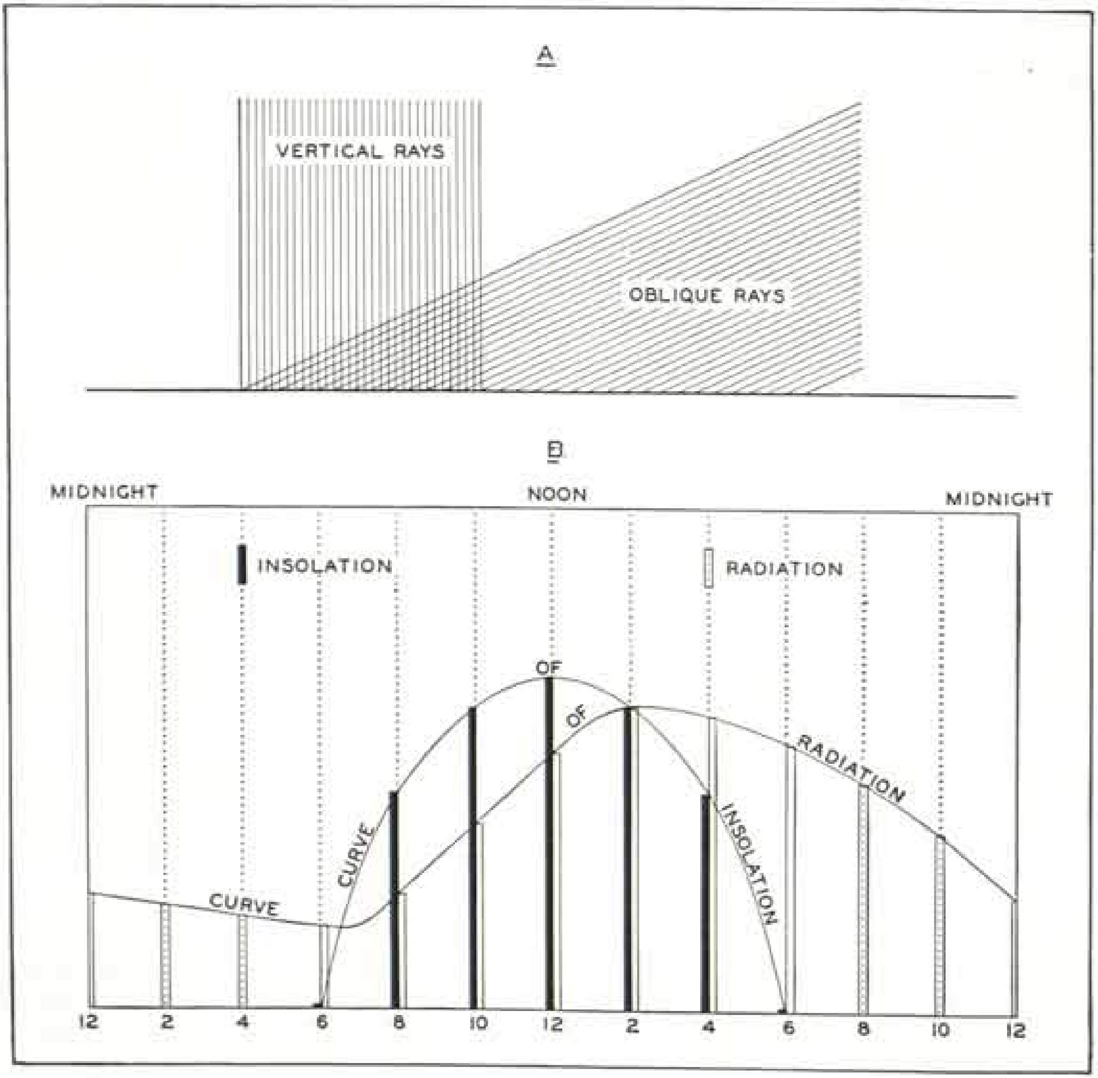


FIG. 82. A. Relative amounts of insolation from vertical and oblique rays of the sun. B. Curves of insolation and radiation for a 24-hour period, with sunrise at 6 A.M. and sunset at 6 P.M.

Damaging frost effects on orchards, where protection by covers is obviously impracticable, may sometimes be prevented by building fires and thus raising air temperatures sufficiently to prevent frost occurrence. In the citrus orchards of California and elsewhere this is accomplished by the use of smudge pots, which burn crude oil and produce a dense smoke. This blanket of smoke probably checks radiation to some extent, though the more important beneficial effect is the higher temperature resulting from burning the oil.

Temperature Ranges. Temperature ranges are of two types: (1) daily; and (2) annual. Daily range is the difference between the maximum and minimum temperatures for the 24-hour period of a day; annual, the difference between the temperatures of the warmest and coldest months of a year. These ranges result from variation in the amount of insolation, or radiant energy, received from the sun during a 24-hour period, in the case of the daily range; and during a year, for the annual range, plus the quantitative relationship of these amounts to the radiation, or loss of heat, by the earth during these same periods.

Daily Temperature Range and Its Effects. The amount of heat received from the sun early in the morning, when the sun's rays are very oblique, is exceedingly small. It is so small that, even for some time after sunrise, the earth actually receives less heat from the sun than is lost by radiation. So long as this continues, the temperature falls. However, as the sun rises higher in the sky, its rays become less and less oblique and their heating power increases correspondingly, until finally the amount of heat received and the amount radiated balance. This is the coldest time of day which, it will be noted, occurs *after* sunrise. Thereafter, the amount of heat received increases up to a maximum at 12 o'clock noon, sun time, when the sun's rays approach or reach the vertical. After this time, noon, the amount of heat received decreases to zero at sunset. Though the amount of heat received is greatest at noon, the hottest time of day is normally later, the exact time varying with the season, for the temperature must increase as long as more heat is received than is lost, and up to the time when radiation equals the amount of heat received. This is usually between 2 and 4 P.M. Daily range varies greatly from place to place. For well-watered areas in low latitudes, especially near the ocean, it will normally be less than 10 degrees. In desert areas, by contrast, particularly where aridity is associated with considerable elevation, temperatures may fall to freezing or below at night, even in the tropics, and rise to 100°F. or more in the heat of the day. This is because both heating and radiation are extremely rapid in the clear, dry air of all deserts, and in the thin air at great elevations.

This daily range of temperature resulting from the variable relation between the rates of heating and radiation is of great importance to man, for it affects both his comfort and basis for support. Certain crops such as potatoes, for example, do well only in areas with cool nights and warm days; others like corn are grown to best advantage where both days and nights are hot. Thus daily range of temperature affects crop *systems*, crop *yields*, and crop *quality*. Further, if both days and nights are hot, though these conditions are favorable for corn, they are not conducive to human comfort, whereas cool nights furnish some respite from hot days and enable man to work more effectively.

Annual Temperature Range and Its Effects. Annual temperature range varies with both latitude and distance from the ocean. At the equator, even at great elevations, the annual temperature range may be less than 1 degree, much less than the daily range for the same place. This is why night is sometimes referred to as the "winter of the tropics." In higher latitudes, especially if far from the ocean, the average annual range is commonly as much as 50, and it may exceed 100 degrees. These extreme temperature changes result from great variation in the amount of heat received at different seasons of the year in all high latitudes, and the rapid heating and radiation where the regulating effect of the ocean on temperatures is lacking. In the same way that the coldest part of the day occurs after sunrise and the hottest part after noon, the coldest part of the year is after the time when the sun's rays are most oblique and the hottest part after they are vertical or most nearly vertical, for here again temperatures on a certain date or during a given season depend not only upon the amount of heat received, but also on the relationship between that amount and radiation. Apparent exceptions to this general rule are explainable by such causes as wind shifts, which alter the temperature conditions normal to an area at a given time by importation of masses of air from other latitudes.

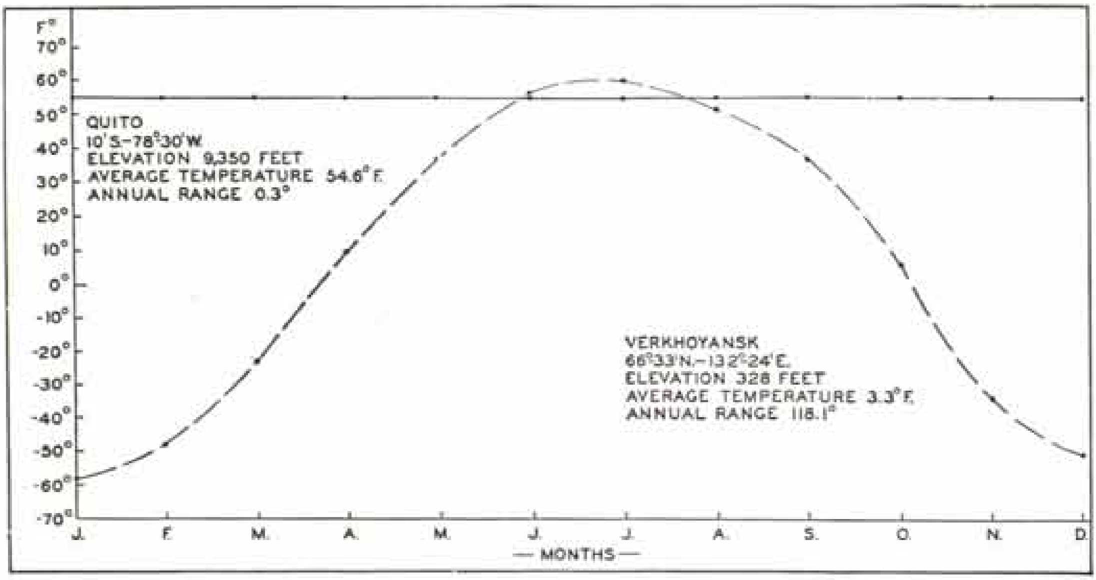


Fig. 83. A contrast in annual ranges of temperature. Quito, at an elevation of 9,350 feet but near the equator, has an annual range of less than 1 degree. By contrast, Verkhoyansk, in a higher latitude near the Arctic Circle and in the interior far from the ocean, has an annual range of more than 118 degrees.

Annual range of temperature influences both man's comfort and his economic activities. It affects plant habits and thereby man, who depends on plants for food and particularly on seeds or other plant structures designed to reproduce the plant species. In the humid tropics, where it is warm throughout the year and conditions are favorable for continuous growth, plant reproduction is commonly by means other than "seeds." Therefore most of man's foodstuffs are supplied by plants which grow where there is a considerable seasonal change of temperature, or in some other aspect of the climate which imposes a resting stage on plant life.

Annual range of temperature produces differences in the crops which can be grown to advantage, not only as between the tropics and intermediate latitudes, but within middle latitudes as well, where temperatures commonly fall below freezing for extended periods of time during the winter months. For example, if winter temperatures are too low, winter wheat, which is fall planted, cannot be grown successfully. Therefore, if wheat is a crop, it must be spring wheat, which gives smaller average yields.

In addition to affecting crops grown, crop yields, and available food supply, annual temperature range is important because of its physiological effect and its stimulus to endeavor. In those parts of the tropics where continuously high temperatures and humidities are enervating, and where necessity for providing against long, cold winters is lacking, these conditions operate to limit present development and impose what appears to be a permanent handicap on that of the future. Even where it is not so hot, but only continuously warm, it is difficult to muster enthusiasm for sustained effort, and much easier to put off until the tomorrow which never arrives the tasks which should be done today. Possibly this is one of the reasons why the populations of such areas are today of but slight and declining importance, whereas those living where there is a considerable annual range of temperature have "inherited the earth."

Elevation, Temperature, and Life. Temperatures normally decrease with elevation. Therefore highland areas have lower actual temperatures than do those at or near sea level in the same latitude. This decrease is at an average rate of about 3 degrees Fahrenheit for each thousand feet of ascent in the lower atmospheres, where man lives. Thus a city such as Quito, in Ecuador, at an elevation of 9350 feet, though only about 12 miles from the equator, has an average annual temperature throughout the year of slightly less

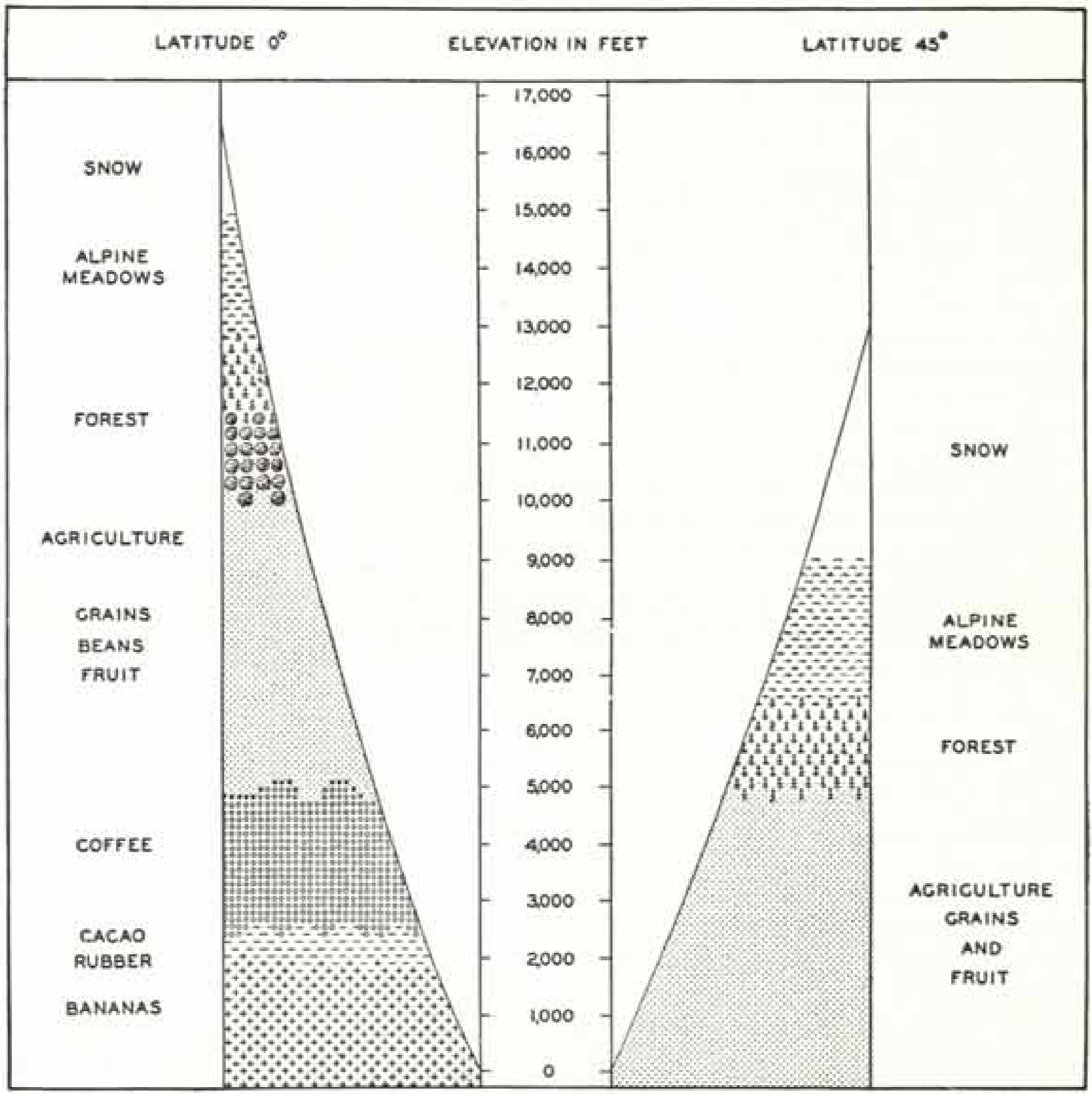


FIG. 84. The zoning of native vegetation and cultivated crops resulting from elevation, in different latitudes.

than 55°F. By contrast, Belém, in Brazil, in approximately the same latitude as Quito but with an elevation of only 33 feet, has an average temperature which, day after day, is about 85°F. Not only does elevation depress actual temperatures, but it also operates to increase the daily range. This is because the earth's land surface heats very rapidly during the daytime as a result of the relatively shallow layer of thin air overhead and radiation is correspondingly active, its effects being particularly marked after sunset. This increases the difference between day and night temperatures, or the daily range.

The lower actual temperature and greater daily range at elevations affect the character of the native vegetation so that it is possible, by traveling short distances in tropical highland regions, to pass from areas with the luxuriant vegetation characteristic of rainy tropical lowlands, through others with plant species resembling those of intermediate latitudes, to the ice-covered slopes of summit elevations, even on the

equator, if the elevation is sufficiently great. Agriculture and the crops grown, as well as the native vegetation, likewise alter with elevation. The lowlands may produce rubber, bananas, and other crops typical of low-latitude agriculture; the intermediate elevations, wheat, maize, beans, and fruits; higher, grazing may supplant agriculture; and at still greater elevations, perpetual snow cover may prevent all productive use of the land.

Tropical highlands of moderate elevation may be a more desirable home for man than are the bordering, hot and steaming, disease-ridden lowlands. Not only are temperature conditions there more conducive to comfort and stimulating to human endeavor, but grazing and agricultural activities made possible by the climatic conditions afford a more satisfactory basis for support and food supply than do those economic activities possible in the tropical rain forest. As has been noted earlier, highland sites were preferred locations for early Indian civilizations of the Americas: those of the Aztecs of Mexico, and of the Incas on the Andean plateaus of South America. In the higher latitudes, elevation does not have the advantages possessed nearer the equator. In fact, it is in general a handicap, for it limits agricultural and other use of the land without compensating advantage.

All highland areas of considerable elevation, both in the tropics and elsewhere, are affected adversely by their "thin" air, which renders physical exertion difficult and makes performance of hard manual labor impossible for any except those populations native to such elevations. It is this thin air which makes ascent of lofty mountains so difficult, and that causes what is known as "mountain sickness." Some individuals are affected so greatly by the lesser density of the air at elevations that they are unable to live even in a city such as Denver, Colorado, though it is only about a mile above sea level. The thin air likewise causes some minor inconveniences in everyday life, such as its effect on the boiling point of water and the operation of automobiles.

QUESTIONS AND EXERCISES

1. In what ways do climatic conditions affect plants? What two climatic conditions will produce deserts? Do these effects of climate on plants extend to animals? If so, in what respects?
2. How does the "plant factory" operate? What raw materials does it use, how and where are these obtained, what product is made, and what supplies the power? During what part of the 24-hour period of each day does the plant factory operate?
3. For what two purposes does the plant use "sugar" or the equivalent material which it produces? What useful purpose does the seed serve from the standpoint of the plant? If possible, name some foods, other than beverages, green vegetables, and condiments, supplied by plants and used by man, which are not derived from seeds or some other structure developed by plants as a means of perpetuating the species. Are there many such foods?
4. In what ways does the percentage of the possible hours of sunshine affect agriculture? Why is a high percentage of sunshine desirable? What part of the United States has the highest percentage of the possible hours of sunshine? How high is this?
5. Why does freezing commonly kill herbaceous plants? Why is a sudden drop of temperature more disastrous to such plants than a gradual lowering of temperature over an extended period of time? At what temperature, on the average, does plant growth stop? Are plants killed at this temperature?
6. What is meant by the frost-free season? Why is its length of importance to man? How does great variability in length of the frost-free season affect man unfavorably?
7. In determining the length of the effective frost-free season, why is knowing the average length frequently of very little practical importance? What should be known regarding the length of the frost-free season in order to have the information necessary to plan intelligently for crop production?
8. What is meant by temperature efficiency? What determines the temperature efficiency of a given area? How does low temperature efficiency handicap agricultural use of an area?
9. How do low temperatures affect animals? State some of the beneficial effects of low temperatures on soils. How do low temperatures affect man? How is it possible for man to live at Verkhoyansk, where January temperatures average nearly $-60°$ F.
10. How do high temperatures affect plants, animals, man, and soils? Do high temperatures alone prevent human occupation of an area? Illustrate by examples.

11. Why are orchards planted on slopes normally free from frost danger and damage? How do lakes protect orchards along their shores from frost damage, both spring and fall? In what ways, other than by selection of a favored location, may frosts and frost damage be prevented? Why does flooding of a cranberry bog tend to protect the crop from frost damage?
12. Why do the vertical rays of the sun possess greater heating power than the oblique rays? At what time of day is heating most rapid? Why? Why does the coldest time of day occur after sunrise? The hottest time of day after noon rather than at noon? How does daily range of temperature affect agriculture?
13. Why is daily range of temperature normally greatest in dry areas, at some distance from the sea, and at considerable elevations? How does this great range of temperature affect living conditions in such areas?
14. What is the annual range of temperature at Quito? Why so small? What is the annual temperature range at Verkhoyansk? Why so great? In what ways does annual range of temperature affect man and his economic activities?
15. Why does temperature normally decrease with elevation? At what rate? How does change of temperature with elevation affect native vegetation and agriculture? What type of native vegetation would occur at an elevation of 14,000 feet near the equator? What crops at an elevation of 8000 feet?
16. Why were areas of considerable elevation preferred to adjacent lowland locations by the Aztecs and Incas, inhabitants of the lower latitudes of the Americas? How and why is man handicapped in living and working at great elevations? Is this true for all population groups, including those native to areas of great elevation?

SELECTED REFERENCES

Blair, T. A., *Weather Elements*, Prentice-Hall, Inc., New York, 1937, pp. 66–130.

This reference discusses solar radiation and its effects, and the cause and prevention of frost. Though somewhat technical, the presentation is probably within the range of understanding of the better students.

Smith, J. W., *Agricultural Meteorology*, The Macmillan Company, New York, 1920.

This elementary text in agricultural meteorology affords an extended discussion of the relation of the various climatic elements to agricultural practices and their effect on different crops.

Trewartha, G. T., *An Introduction to Weather and Climate*, McGraw-Hill Book Company, Inc., New York, 1943, Chap. I.

The chapter suggested for reading is concerned with air temperatures. If additional reading on this topic is desired, the bibliography at the end of the chapter suggests some possibilities.

Chapter Twelve

CLIMATIC ELEMENTS: ATMOSPHERIC HUMIDITY AND DUST

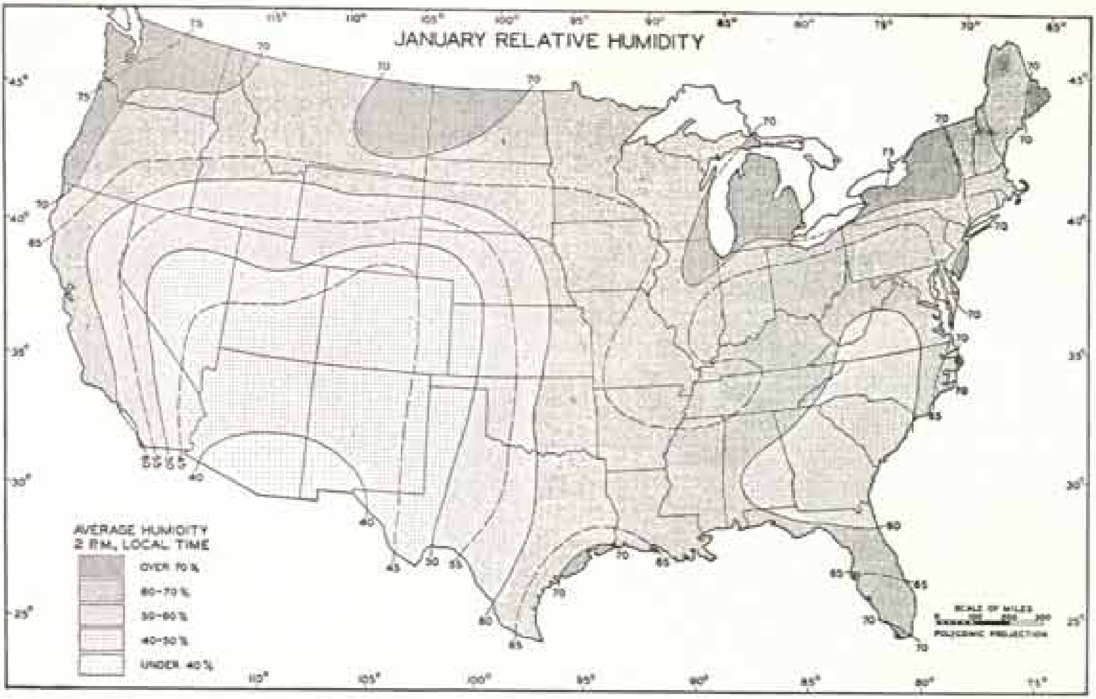
Water and Its Forms. Water exists in nature in different forms at temperatures which are of normal occurrence in everyday life. Below 32°F. it is commonly a solid, though it may likewise be present in gaseous form in the atmosphere. At temperatures between 32°F., its freezing point, and 212°F., its boiling point, water may exist either as an invisible gas, as in the air, or in a liquid state. Above 212°F., it usually assumes a gaseous form. However, in all these forms, solid, liquid, gaseous, and the variations of each, it remains unaltered except in physical condition; and the different names, ice, water, steam, and others, are desirable only because all occur at temperatures within the range of daily experience.

WATER-HOLDING CAPACITY OF THE AIR AT SELECTED TEMPERATURES

Temperature Fahrenheit	*Water-holding Capacity in Grains per Cubic Foot*
−40°	0.050
−20°	0.166
−10°	0.285
0°	0.481
10°	0.776
20°	1.235
30°	1.935
40°	2.849
50°	4.076
60°	5.745
70°	7.980
80°	10.934
90°	14.790
100°	19.776

Water-holding Capacity of Air. From the preceding table, it will be observed that the ability of the air to hold water increases greatly as the temperature rises. For example, air at a temperature of 100°F. can hold approximately 40 times as much water as air at 0°F. Because the ability of air to hold water is so great at high temperatures, warm air ordinarily contains more water than cold air. For this reason, the amount of water in the air is normally greatest at the hottest time of the day and year and least at the time of day and year when temperatures are lowest. This small water-holding capacity of the air at low temperatures should suggest why cold areas in high latitudes always have light precipitation, whereas in low latitudes, where the air is warm, precipitation is frequently very heavy. It likewise explains in part why summer precipitation is often heavier than that of winter, and why there are few clouds at great elevations. The precipitation at Verkhoyansk in central Siberia, for example, illustrates the effects of low temperatures on both the distribution of precipitation and its total amount. During January, when the average temperature is −58.2°F., there is practically no water in the air, less in fact than in the air over equatorial deserts where temperatures are high. This is one reason why precipitation is only 0.2 inches for the month. By contrast, during July in the same area, when the average temperature is 59.9°F., the precipitation is 1.1 inches, or five and one-half times as great. Because of the generally low temperatures which prevail throughout the year, however, the total annual precipitation is only 5.2 inches, which is less than that of most tropical deserts.

This relationship between temperature conditions, the ability of the air to hold water, and the possibility of its loss by precipitation finds expression in the weather proverb: "It is too cold to snow." Certainly, if temperatures are low, the air cannot hold nor can it lose much water, for it



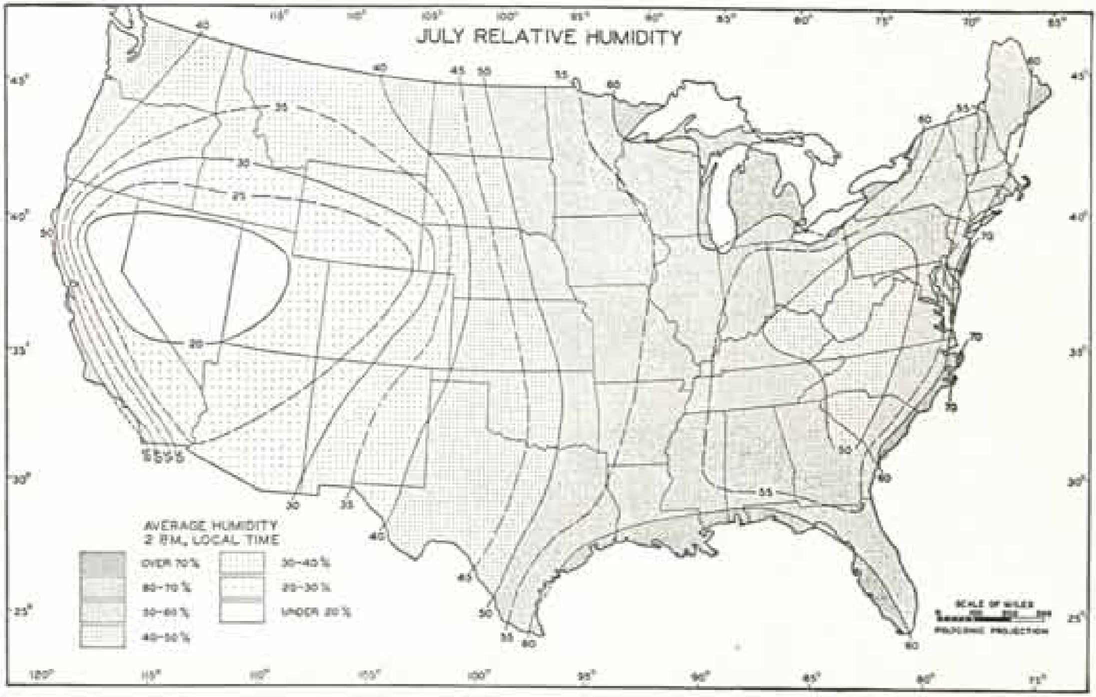


FIG. 85. Comparison of January and July relative humidities as shown by the two maps above will reveal marked seasonal differences which reflect both temperature and wind effects. In the Dakotas and Montana, where a summer maximum of precipitation occurs, January relative, though not absolute, humidities are often 30 per cent higher than those of July. On the west coast where most of the precipitation occurs during the winter months, January relative humidities are sometimes 35 per cent greater than during July. (After the Atlas of American Agriculture.)

has little to lose. Therefore it may be at least too cold to snow very much. Thus temperatures influence the amount and distribution of precipitation, thereby making certain areas desirable and others undesirable for human occupation.

Water Content of the Air: Absolute Humidity. Though not a component of the air, water is always present in the atmosphere in variable amounts. Therefore it is frequently desirable to be able to express quantitatively how much is present under the conditions existing at a given time. This may be done by stating the amount of water by weight in a given volume of air, for example, the number of grains of water per cubic foot of air. This is known as a statement of the absolute humidity of the air.

Water Content of the Air: Relative Humidity. The water content of air may also be expressed as a percentage relationship between the amount of water by weight in a definite volume of air and the amount an equal volume of air could hold under the same conditions of temperature and pressure. For example, if 1 cubic foot of air at 70°F. holds 4 grains of water, it contains one-half or 50 per cent of what it is able to hold at that temperature. Therefore its relative humidity is said to be 50 per cent. Inasmuch as increase in temperature without other change enables air to hold more water but does not increase the actual amount present, raising the temperature decreases the relative humidity; and, conversely, decreasing the temperature increases the relative humidity, if other conditions are not altered. It is also apparent that the relative humidity of air may be high when the absolute humidity is low, if the air is cold; and that relative humidity may be low when the absolute humidity is high, if the air is highly heated. From these facts it follows that relative humidity will normally be highest at the coldest time of the day and year, and lowest at that time of the day and year when maximum temperatures occur. This, it will be observed, is the reverse of conditions which obtain with absolute humidity.

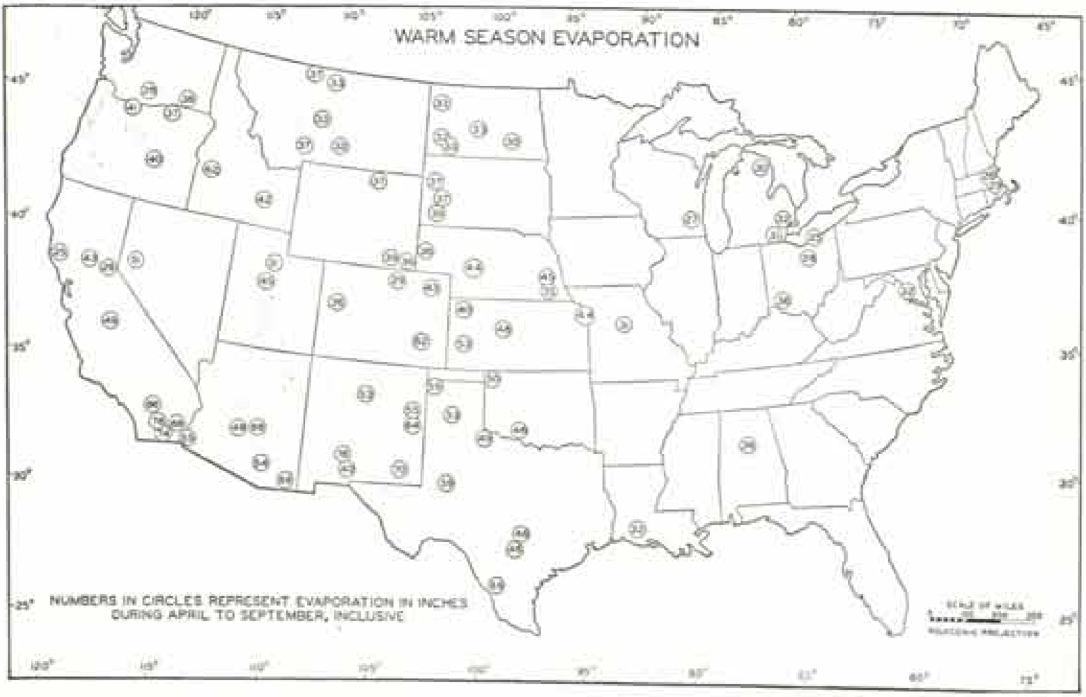


FIG. 86. This map shows that warm season evaporation varies greatly in different parts of the United States. Consequently the water requirements for a given crop will vary correspondingly. Comparison of this map with the one showing total precipitation for the year, Fig. 98, will reveal that warm season evaporation, or the possibility for such evaporation, exceeds the annual precipitation in some areas; in others it is less. Where in excess, agricultural use of the land is handicapped and possible only by the use of dry farming methods or with irrigation. (After the Atlas of American Agriculture.)

The Dew Point. If air at 70°F., which can hold approximately 8 grains of water per cubic foot, actually contains 4 grains per cubic foot, its relative humidity will be 50 per cent. If this air is cooled to 40°F., its relative humidity will become 100 per cent, for at 40°F. it can hold only 4 grains of water per cubic foot (an approximation, for simplicity). If this air is cooled below 40°F., it will ordinarily no longer be able to hold all of the 4 grains, for under normal conditions relative humidity cannot exceed 100 per cent. Therefore part of the water in the air will condense on surfaces such as cold windows and cold water pipes. The temperature at which such condensation occurs is known as the "dew point."

Rate of Evaporation. Three factors important in determining the rate of evaporation are: (1) temperature of the air and the source of evaporation; (2) wind; and (3) relative humidity. Other conditions remaining constant, the higher the temperature the more rapid the evaporation, for high temperatures increase both loss from the source and the ability of the air to hold water. A strong wind likewise facilitates the passage of water from the liquid to the gaseous condition by removing saturated air from contact with the evaporating surface, replacing it with air which has the ability to absorb moisture, thereby maintaining constant evaporation. Relative humidity influences rate of evaporation by affecting the ability of the air to absorb moisture. When relative humidity is high, for example, less additional water can be taken up by the air than would be the case were it low. What is meant by "dry air" is air in which wet objects will dry rapidly, that is, air with a low relative humidity; "moist air," or air in which wet objects will not dry rapidly, is air with a high relative humidity. Thus the optimum conditions for drying wet objects are a high temperature, a strong wind, and a low relative humdiity.

Instruments for Determining Relative Humidity. Most instruments for determining relative humidity depend upon the fact that evaporation is more rapid in dry than in moist air. They assume different forms and are given various names dependent on the type of the instrument, but all are included under the general name of "hygrometer," or measurer of moisture. Sometimes, when designed for popular use, they are known by a trade name such as "Humidiguide," descriptive of their function.

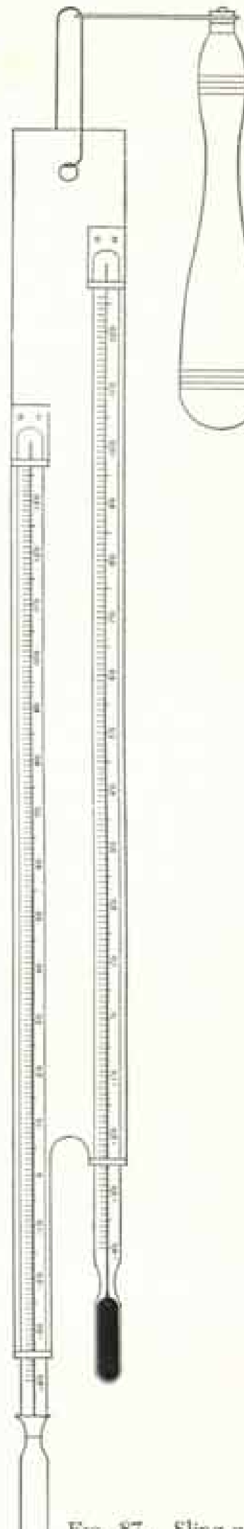


FIG. 87. Sling psychrometer.

The type of hygrometer shown in Fig. 87, a sling psychrometer, consists of two thermometers. One, the "dry-bulb" thermometer, is designed to record the air temperature. The other, the "wet-bulb" thermometer, has its bulb covered with a moistened wick. When this thermometer is whirled to promote evaporation, cooling produced by evaporation from the wick causes it to register a lower temperature than that recorded by the dry-bulb thermometer. Since the rate of evaporation determines the amount of cooling, the drier the air, or the lower the relative humidity, the greater the difference between the readings of the two thermometers. Thus a considerable difference indicates a low relative humidity; a slight difference, a high relative humidity. The exact humidity indicated by the temperature difference registered is in practice obtained from a table which supplies the relative humidity as a percentage. With instruments designed for popular use, the humidity is generally registered directly by the instrument.

Effects of Humidity on Human Comfort. The ordinary thermometer registers actual air temperatures, but that reported by the senses, or the "sensible temperature," is often different, for it is determined by a variety of factors and particularly by humidity. On a hot muggy day in summer, for example, when humidity is high, the sensible temperature will be higher than it would be were the relative humidity low and the air dry. This is because the high relative humidity prevents rapid evaporation and so deprives the body of the cooling effect of such evaporation, which goes on rapidly in dry air. The variable effect of different relative humidities on this cooling process is shown in the accompanying tabulation.

Air Temperature, degrees Fahrenheit	*Relative Humidity, per cent*	*Temperature after Lowering by Evaporation (Reading of the wet-bulb thermometer of a hygrometer, in degrees Fahrenheit)*
90	71	82
90	47	74
90	13	60

Data based on a barometric reading of 30.00 inches.

To obtain some relief from oppressive heat when both the temperature and relative humidity are high, an individual may either fan himself or sit in the breeze of an electric fan. This does not alter the actual temperature of the air, but it does remove the air as it is heated by the body, and, more important, it increases the rate of evaporation of perspiration, thereby producing a considerable amount of cooling. Because of this function of evaporation, the high air temperatures of desert areas, where relative humidities are low, may be quite tolerable, whereas those of humid regions with somewhat lower actual temperatures may be very trying.

As has been noted earlier, high air temperatures alone do not deter man from living in an area, for the highest known air temperatures are associated with low relative humidity and tolerable sensible temperatures as a result of that fact. In Death Valley, one of the hottest spots on the earth's surface, for example, temperatures may rise to 112°F. in the shade many days each summer, but the reading of the wet-bulb thermometer of the hygrometer on those same days will range from 70° to not more than 80°F. Even extreme temperatures as high as 118°F. or more are not intolerably hot, for the dew point will then be below freezing, and the wet-bulb thermometer may record a temperature as low as 70°F. because of the exceedingly dry air. Therefore, if one does not expose himself to the direct rays of the sun or to hot winds in such areas, he suffers relatively little discomfort and incurs essentially no risk of prostration by heat. In fact, heatstrokes are rare in the dry West, with its high temperatures, though not uncommon in the humid eastern and central United States, where both actual and sensible temperatures may be very high during "hot waves," or periods of high temperature during the summer months.

Somewhat similarly, low temperatures cause less discomfort on a cold but dry and quiet winter day, or one with "dry cold," than on one that is damp and "raw." This is especially true if it is windy as well. This results from the more rapid loss of body heat at low temperatures when the air is moist and changes rapidly with a strong wind. From the standpoint of human comfort, then, sensible temperatures are more important than actual temperatures. This explains in part why areas with the same actual temperatures differ so greatly in relative desirability, and why an area may be sparsely populated because it is too wet: one of the three repressive types of environment.

Indoor Humidity. During the summer months, indoor relative humidity averages higher than

that of outdoors because of the lower indoor temperatures. This is what causes doors to swell so that they will not close, or close with difficulty, and drawers to stick so that they will not pull out during humid summer weather. During the colder months of winter, however, when houses are heated, indoor relative humidities are frequently very low. This is especially true in the coldest weather, for the lower the outdoor temperature, the more frequent the interchange of indoor and outdoor air. If this air which is admitted to the house from the outside has a temperature of 0°F. and a relative humidity of 50 per cent, it contains approximately ¼ of a grain of water per cubic foot, but, after being heated to 70°F. indoors, it is able to hold about 8 grains of water per cubic foot. Therefore the relative humidity after heating drops to slightly over 3 per cent. With further reduction of either the outdoor temperature or humidity, indoor relative humidities become even lower. This is the reason why a furnace-heated house, without any provision for air conditioning, is sometimes said to be the driest place on earth, for the indoor humidities under such conditions may be as low or even lower than in the driest of deserts.

Such excessively low indoor relative humidity is detrimental. Evaporation is so rapid that woodwork and furniture dry out and joints open. The mucous membranes of the body likewise suffer from excessive loss of water; the throat becomes irritated and raw; and the incidence of colds is increased. Hands chap; the lips crack; and the air feels "parched" or "burned," causing personal discomfort. These low indoor relative humidities likewise result in low sensible temperatures which cause houses to be kept too warm in order to ensure comfort. This increases the fuel bill and intensifies the other disadvantages by promoting still more rapid evaporation. To remedy these objectionable conditions, it is becoming a common practice to humidify the air but to accomplish this in cold weather a surprisingly large amount of water must be added, for at such times the air changes at least every hour and sometimes as often as every 20 minutes in the average house. On the assumption of but one change each hour, if the outdoor air has a temperature of 0°F. and a relative humidity of 50 per cent, and the indoor temperature is kept at 70°F., to maintain a relative humidity of 50 per cent in a room 12 by 15 feet with a 9-foot ceiling, it is necessary to add approximately 9 quarts of water each 24 hours.

Another problem which arises when humidification of the air is attempted is that of condensation on cold surfaces: on windows, in the partitions, in the attic or under the roof, and in all other cold parts of the house into which the warm, humidified air finds its way. This condensation occurs in the form of frost which, on melting with higher temperatures, may cause considerable damage. This danger of objectionable condensation imposes a limit on the degree of humidity which can be maintained in practice, especially in areas with very severe winters.

Some Additional Effects of Humidity. Relative humidity affects both plant structure and the water requirements of crops, the latter being a factor in determining the crop system of a given area. Where relative humidity is low, as in the deserts of the lower latitudes, plants expose only a small amount of leaf surface. Otherwise, evaporation would proceed more rapidly than the plant could draw water from the relatively dry soil, and the plant would wilt and die. In humid areas, by contrast, an enormous amount of leaf surface must be exposed to permit sufficient evaporation from the plant for the effective functoining of certain vital life processes. Thus plants show by their appearance whether they are native to areas of high or low relative humidity.

The rate of evaporation likewise affects the water requirements of a given crop. When high, the crop requires much water; when low, it requires less. Thus in general it requires less water to grow a crop of wheat in Montana than it does in Texas, where higher temperatures decrease relative humidity and increase the rate of evaporation. These conditions permit greater diversification of agriculture in the higher latitudes, as well as enable agriculture without irrigation to push farther west in the northern than in the southern Great Plains region of the United States.

The effect of humidity on the water requirements of crops becomes especially important in those irrigated areas where practically all the water required for production must be purchased, for the more it is necessary to buy, the less profitable is agricultural use of the land. Relative humidity may in this way become an important, or even a critical factor, in determining the possibility of profitable agriculture in certain areas.

Relative humidity likewise affects the fre-

Fig. 88. Typical dust storm, Baca County, southeastern Colorado. The dried-out soil, blown by the wind, decreases visibility, at times to zero. Note the drifts of soil around the fences and other obstructions. (Courtesy of the U. S. Soil Conservation Service.)

quency and severity of dust storms and the probability of forest fires, for when relative humidity is low, evaporation is rapid, and both soils in agricultural use and the loose material on the forest floor dry out rapidly. In the first instance, this creates conditions favorable for dust storms, as the dried-out soil is moved easily by the wind; in the second, it makes forest fires more apt to start and more rapid in their spread.

Atmospheric Dust. Atmospheric dust is made up of solid particles which float in the air. These are so small that they are kept in suspension by air currents, so small in fact that they are invisible under most conditions. When a beam of sunlight crosses a darkened room, however, the air in its path is seen to be filled with thousands of them, all small but of varying size, and all in constant motion as air currents cause them to shift position. Though it is only in the path of the light that they are visible, the surrounding air is equally crowded with similar solid particles.

Origin of Atmospheric Dust. Part of the dust consists of minute mineral fragments; another part is of organic origin. The particles of mineral matter probably come from the exposed soil of some dried-out field. Along the seacoast, they may even include salt grains left in the air by the evaporation of wind-driven ocean spray. Sometimes, also, part of the dust is finely fragmented material ejected at the time of a violent volcanic eruption such as that of Krakatoa, described in an earlier chapter. During this particular eruption, dust is known to have risen to great heights, to have spread far and wide over the surface of the earth, and to have remained in the air for several months. The organic particles of the dust may be fragments of disintegrating plant or animal material; soot from forest fires; plant spores; or microorganisms, including disease-bearing bacteria. In addition, human occupation of the earth has in recent years added another important source of atmospheric dust: soot from chimneys, particularly important both in and near our larger industrial centers, for the smoke of industry is often visible miles beyond city limits.

Amount of Atmospheric Dust. The amount of atmospheric dust varies greatly from place to place. In the upper air, around high mountain

peaks, in the Arctic and Antarctic, and over the oceans, the air is relatively free from solid particles, for a near-by source of supply is lacking. Elsewhere, and especially where man occupies an area in considerable numbers, there is much dust in the air. Even agricultural practices add large amounts, for with each plowing or other working of moderately dry soil, a cloud of dust marks the course of cultivation. With important industrial development, conditions become much worse. A pall of smoke then blankets the earth's surface, sometimes to an extent that artificial illumination becomes necessary when the unobscured sun is shining brightly elsewhere.

The amount of dust in the air likewise varies from time to time in the same place. During forest fires, for example, there may be so much smoke in the air that it will be hazy many miles distant from the actual fire, even to the point of reducing visibility to an extent that traffic becomes hazardous and lights must be burned at midday. By contrast, after a rain the air has been "washed," and a large part of the dust has been removed. Similarly, during periods of calms much of the dust in the air settles to the ground. In most cases, the amount of dust lost in this way is not large, but after a severe dust storm the quantity may be considerable, so great indeed that over an extended period of time a layer many feet in thickness, from which soils are derived, may accumulate from a succession of such storms. This is true on the plains of North China, where strong, dust-laden winds blow from the interior of Asia during the winter months of the year.

Smoke in City Air. There is much smoke in the air of all our great industrial cities, so much that the yearly loss caused by soot, the unburned particles of carbon making up smoke, is estimated at \$2,500,000,000. Part of this loss results from the fact that smoke represents unburned fuel, but the larger part is caused by the direct damage to buildings, vehicles, house furnishings, clothing, and by increased light bills. Important also is the fact that smoke affects both efficiency and health conditions adversely.

No large city is completely free from smoke, but the amount of soot in the air varies greatly in different urban centers. Where good grades of coal are burned, and city ordinances which are enforced prohibit apartment houses and factories from belching forth great clouds of smoke from their chimneys, conditions are fairly good; where low-grade coal is burned, and no steps are taken to abate the smoke nuisance, conditions are deplorable. Therefore even relatively small urban centers may suffer a considerable handicap as a result of too much smoke in the air.

In 1930, St. Louis afforded an excellent illustration of undesirable smokiness. Conditions were so bad, indeed, that downtown visibility was sometimes less than a quarter of a block, and it was necessary to burn lights in the middle of the forenoon. Even the residential sections were blanketed to an extent that the sun was obscured, though shining brightly in suburban areas. Such "blacking out" finally forced remedial action, so that conditions are now much better, though still not ideal.

Other large industrial centers are similarly afflicted. As one approaches the city from the west, the smoke of Detroit is plainly visible at least 10 miles beyond the city limits. In Chicago, it is estimated that 395 tons of soot fell on each square mile of the city area in 1941, and 1000 tons, or enough to fill 20 railroad cars, on the streets, building, merchandise, and people of the loop district. Yet conditions are no worse, nor even so bad, in Chicago as in some other cities. In Pittsburgh, widely but not favorably known for its smokiness, the amount of soot deposited per square mile of city area is estimated to rise to 1000 tons. Even in the suburbs there is so much soot in the air that nearly 20 quarts of dirt, mostly soot, can be filtered from the air of an eight-room house in the course of a year. If such filtration of the air were a common practice, even though it did not remove all the solid particles, much work and expense would be saved, and probably better health conditions would be ensured.

Importance of Dust in Nature and to Man. Apart from the economic importance of soot which has been considered briefly, the atmospheric dust fills several functions. First, it supplies solid particles which serve as nuclei around which water condenses to form the droplets of fogs and clouds, and the larger drops of water which fall as rain. It also gives us the color of the sky and the phenomenon of twilight. Therefore dust-free air, though possibly desirable in some respects, would alter some of the phenomena and the appearance of nature materially, and probably not to our advantage or liking. It is to

be noted, then, that dust in the air is not necessarily objectionable, but that it becomes so when the amount increases unduly, and particularly when much of the dust is soot, which may, and often does, have effects quite different from those produced by minute grains of mineral matter derived from the soil, plus some organic material not necessarily detrimental in character, which make up most of the dust of sparsely populated regions.

QUESTIONS AND EXERCISES

1. What effect does temperature have on the ability of the air to hold water? How does this affect absolute humidity at the hottest time of day? At the coldest time of day? In summer? In winter?
2. Why is precipitation normally heavier in low than in high latitudes? What is the basis for the weather proverb: "It is too cold to snow"? Is it actually ever too cold to snow?
3. What is meant by "dry air"? By "moist air"? Do these descriptions of the moisture characteristics of the air refer to its absolute or its relative humidity? Why? At what time of day will relative humidity be highest on the average? At what time of day will it be lowest? Why?
4. Under what conditions may the relative humidity be low, the absolute humidity fairly high? Name an area where these conditions occur. Under what conditions may the relative humidity be high and the absolute humidity low? Name an area where these conditions occur. During what season of the year will they be most common?
5. How does the absolute humidity of the air over polar areas in winter compare with that of the air over deserts in lower latitudes? How do such conditions affect precipitation and its seasonal distribution? Illustrate by using the precipitation of Verkhoyansk as an example.
6. State the factors which affect the rate of evaporation and explain how each operates.
7. Name the instrument used in determining relative humidity. Explain the principle upon which the sling psychrometer operates.
8. How does relative humidity affect human comfort outdoors in winter? In summer? Why? Why is indoor relative humidity in heated houses during the winter months detrimental to man? Why is it impracticable to maintain a high indoor relative humidity during the winter months where temperatures are very low?
9. How do humidity conditions affect agricultural practices, yields, and profits? Why is relative humidity of the air especially important in irrigated areas of dry regions?
10. What effect, if any, does relative humidity have on the prevalence of dust storms and forest fires? Why is it difficult to bring forest fires under control during periods of low relative humidity?
11. Of what does the dust of the atmosphere consist? What makes up the bulk of the dust of the air outside of large cities? Of that of the air of large cities? What components of the dust of the air are harmful? Why?
12. Over what parts of the earth's surface is the air relatively free from dust? Why? Is the amount of dust in the air over a given area constant? If variable in amount, why?
13. What is smoke? How much damage is smoke estimated to cause each year in the United States? What causes this enormous financial loss? Why do cities vary greatly in smokiness? Illustrate this variation by examples.
14. Does atmospheric dust serve any useful function? If so, what? For what phenomena of nature is atmospheric dust necessary? If all dust were removed from the atmosphere, what changes would you observe in nature? Would these be to your liking? Why?

SELECTED REFERENCES

Blair, T. A., *Weather Elements*, Prentice-Hall, Inc., New York, 1937, pp. 44–57.

The pages suggested for reading contain a discussion of atmospheric humidity, a description of instruments used for its measurement, and a consideration of evaporation.

Trewartha, G. T., *An Introduction to Weather and Climate*, McGraw-Hill Book Company, Inc., New York, 1943, pp. 141–150.

The pages cited consider the source and importance of water vapor, the hydrologic cycle, humidity and its measurement, and related topics.

Ward, R. D., *The Climates of the United States*, Ginn and Company, Boston, 1925, Chap. XII.

This chapter treats relative humidity and its distribution, absolute humidity and its distribution, evaporation, sensible temperature, measurement of sensible temperature, and sensible temperatures in the United States. Treatment of sensible temperatures is particularly good.

Chapter Thirteen

CLIMATIC ELEMENTS: FOGS, CLOUDS, AND PRECIPITATION

Condensation of Atmospheric Moisture. Whenever the temperature drops so much that the air cannot hold all of its gaseous water content, part may condense around dust particles present in the air. This process is particularly rapid if many of the solid particles making up the dust are hygroscopic, or capable of absorbing water. Since such hygroscopic particles are present in considerable numbers in all surface air, condensation will always occur if the temperature is lowered sufficiently. The drops of water formed in this manner are very small, ranging from 1/1250 down to 1/25,000 of an inch in diameter so that, like the dust particles, they remain in suspension in the air. When this condensation of water from the air occurs at or near the earth's surface, a fog results; when at some distance above the ground, a cloud is formed. In fact, there is no fundamental difference between a fog and a cloud except that of location with reference to the earth's surface; a fog may even be described as a "stratus cloud near the ground" with essential accuracy.

Fogs. Fogs, then, result from cooling the air and condensation of gaseous water the air is unable to hold at the lowered temperature. They are, therefore, of more frequent occurrence in depressions, as over marshes and lakes, than on adjacent higher land because, as air cools, it flows down the slopes and accumulates as pools at the lower levels. This cooler air in depressions, no longer able to hold all of its water, loses part and fog forms.

The minute drops of water which make up fog form around dust particles, as stated earlier. Therefore the more such solid material in the air, the greater the probability of dense fogs. Many cities are very smoky, their air containing enormous numbers of particles of soot which facilitate condensation of moisture when the temperature is lowered. Further, the smoke darkens the fog and decreases visibility. Under such conditions, the fog which results is sometimes known as "smog," the name being derived by combining parts of the two words: smoke and fog. London's celebrated "pea soup" fogs, which are of this type, are probably the densest in the world, so dense as to interfere seriously with traffic.

Fogs may disappear by either "falling" or "rising." When they fall, it is because the drops of water become too large to be kept in suspension by air currents. Therefore they drop to the ground, wetting walks and other surfaces. When fogs rise, the water returns to the air from which it was condensed, as the sun rises and the temperature increases to an extent to enable the air to hold the moisture. A falling fog indicates that the air is saturated with water; one that rises, that the air is able to hold more moisture. The former is an indication of probable precipitation and bad weather; the latter, of clear weather to follow.

Seasons of Occurrence of Fog. Fogs are more common in most areas during the colder part of the year, for conditions favoring condensation are less frequent when the air is warm, at which time its moisture-holding capacity is high. Thus the dense fogs of the Puget Sound region of the United States are much more numerous during the colder months than in summer, for from early fall until late spring the relatively warm, moisture-laden winds bringing air from over the ocean are cooled by contact with the considerably colder land. Further, relative humidity is higher at this time of the year. (See Fig. 85.) Therefore a slight lowering of temperature will produce condensa-

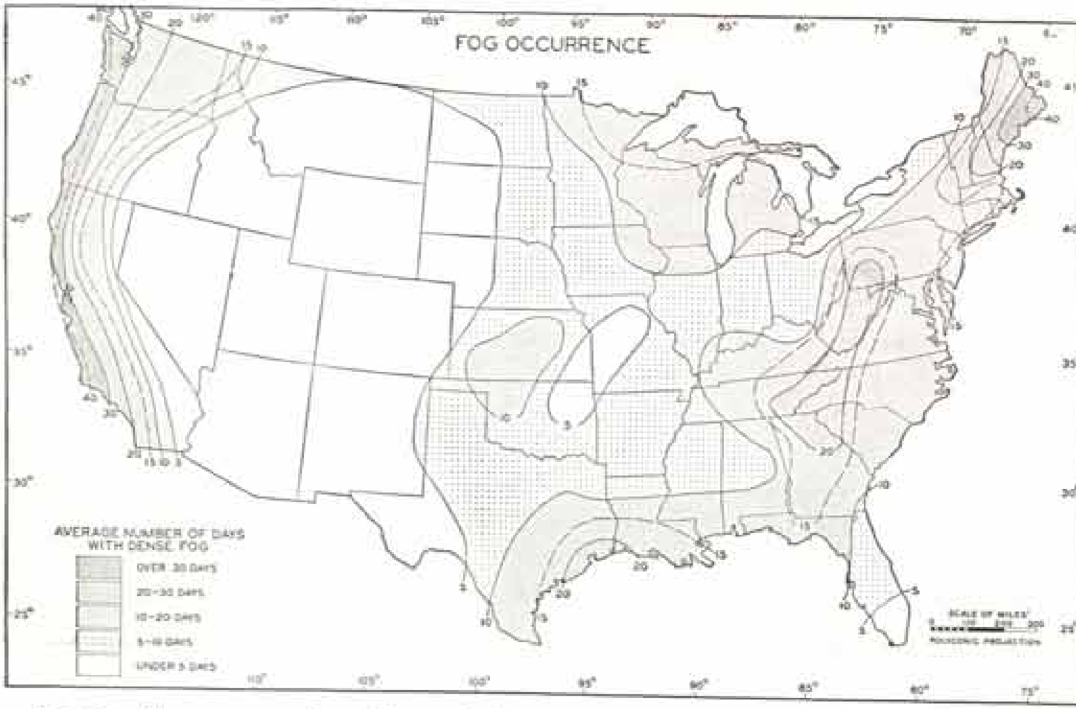


FIG. 89. The average number of days with dense fog each year varies from less than 5 in the western Great Plains to more than 40 along parts of the coast of Maine and most of the Pacific coast of the United States. A dense fog is defined as one thick enough to obscure vision at a distance of 1000 feet. (After the U.S. Weather Bureau.)

tion, whereas in summer the cooling must be greater because of the lower relative humidity during the warmer months. Summer fogs are not unknown, however, and, in certain areas, as along the coast of California and the shores of Lake Superior, they are both frequent and often dense.

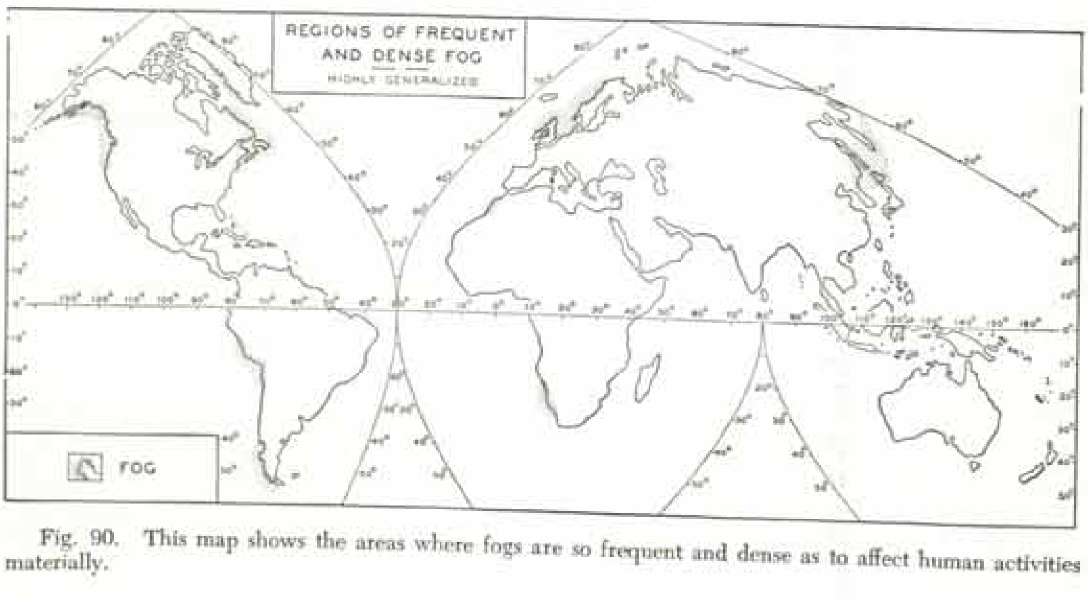


Fig. 90. This map shows the areas where fogs are so frequent and dense as to affect human activities materially.

The coastal fogs of California are caused by comparatively warm, moisture-laden sea breezes blowing over cold water which wells up along the land margin. This causes fogs, densest from 4 to 6 miles offshore, but affecting a narrow strip of land west of the Coast ranges to an extent that visibility is often low. Inland, there is no fog, for it is "dissolved" by the highly heated air of the interior valley. The summer fogs along the north shore of Lake Superior, where fog appears to pour in from the lake and through breaks in the bordering highland afforded by river gaps, only to be dissipated a few miles inland, are caused by condensation of water from the warm air over the land by cool lake breezes.

Areas of Occurrence of Dense Fogs. One type of area where fogs are more than ordinarily prevalent is west-facing coasts in the higher middle latitudes, such as the west coast of North America from central California to the Aleutian Peninsula of Alaska, the west coast of southern Chile, and the coasts of northwestern Europe. These areas lie in latitudes where the winds blow prevailingly from the west, bringing relatively warm, moisture-laden air to the colder land, where the moisture is condensed to appear as fog, especially during the winter months. Another type of area with much fog is located where warm and cold ocean currents meet, for example, in the vicinity of Labrador and Newfoundland, where the Gulf Stream and the Labrador Current make contact; and off the northern island of Japan, Hokkaido, where the Kuroshio, or Japan Stream, meets the Owashio, or Okhotsk Current. Other parts of the world where fogs are frequent and dense are along the coasts of Peru and northern Chile; in Southwest Africa, south of the equator; and, to its north, along the west coast of Morocco. Despite the fact that these are dry or even barren desert areas, with rain almost unknown, the moisture imported by sea breezes makes the climate unpleasant, and, according to Kendrew, so damp that iron rusts rapidly and fabrics and leather mold. In the United States, heavy fogs are numerous on the coast of Maine, along most of the Pacific coast, and on the shores of Lake Superior and the other Great Lakes. They are likewise of frequent occurrence in the rough country of the southern Appalachians and the Allegheny-Cumberland Plateau, where topographic conditions favor concentration of cold air and consequent condensation of moisture.

Economic Significance of Fogs. Fogs are seldom, if ever, of economic benefit. When they occur in summer, they handicap agriculture by limiting the number of crops it is possible to grow at a profit and by affecting yields adversely. In certain areas, as in the eastern portion of the northern island of Japan, Hokkaido, they eliminate agriculture completely. At all times of the year, fogs multiply the hazards of transportation and travel on the land, by air, and over the great ocean highways of the North Atlantic and other seas by decreasing visibility and increasing the danger of collision and shipwreck. Because of the difficulty of landing planes during fogs, considerable expenditures of time and money have been made to discover means of dissipating them over flying fields, without much peacetime success as yet, though experimentally feasible and possible if the cost is immaterial, as during war. Locally, as along the north shore of Lake Superior, where the resort business is an important source of local income during the short summer season, fogs decrease the trade and receipts of hotels, lodges, and camps, even causing them to operate at a loss during an occasional summer with more than a normal amount of foggy weather. Fogs are also generally thought to affect health conditions unfavorably because they cut off sunlight, and they always increase living costs by making artificial illumination necessary during the daytime.

Clouds. When condensation of water from the air occurs at some distance above the surface of the earth, the resulting phenomena are known as "clouds." These are named according to their appearance, form, and arrangement. If the cloud results from an ascending convection current, an air movement caused by temperature differences, condensation will begin at an elevation varying from 1800 to 4000 feet, dependent on temperature and humidity. Above the horizontal base, located at the level at which condensation begins, the cottony-appearing masses of the so-called "cumulus" cloud extend to great heights, often several miles. Low-lying clouds, normally not much more than 1000 feet above the earth's surface, if arranged in bands or layers are known as "stratus" clouds, but, if they are thin and fleecy, and at elevations of 5 miles or more, they are called "cirrus" clouds. At such great heights, temperatures are so low that water freezes. Therefore cirrus clouds are composed of minute particles of ice rather than of water in a liquid

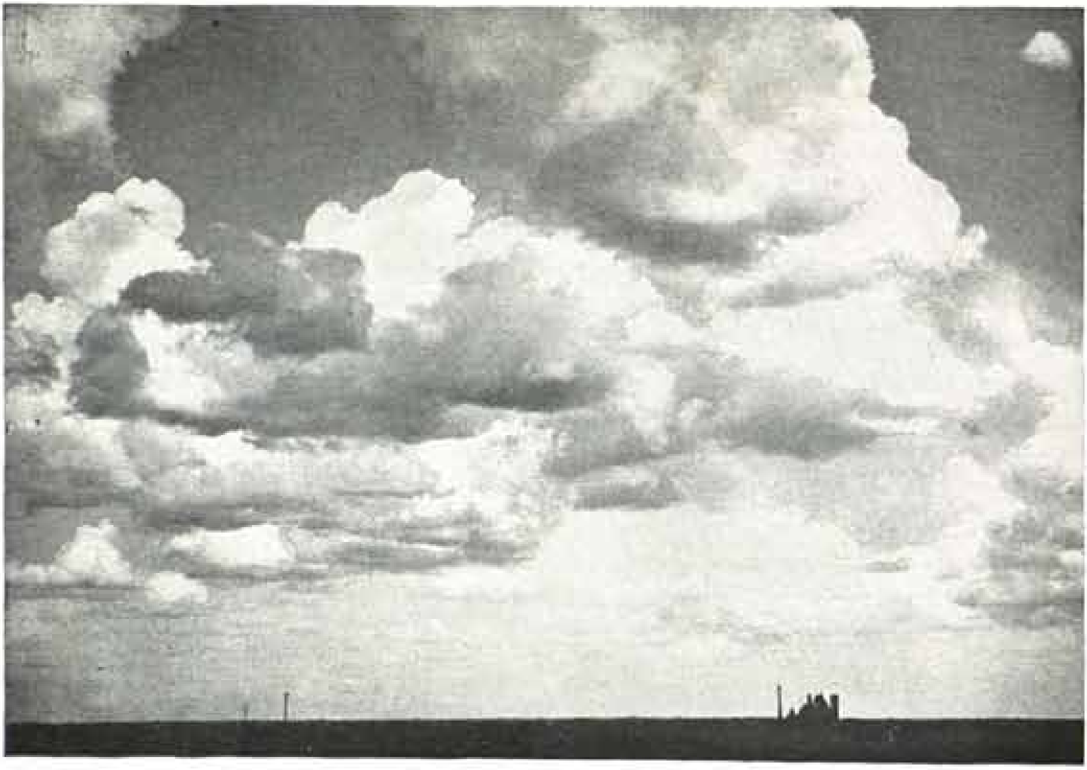


FIG. 91. Cumulus clouds. (Courtesy of the U. S. Weather Bureau.)

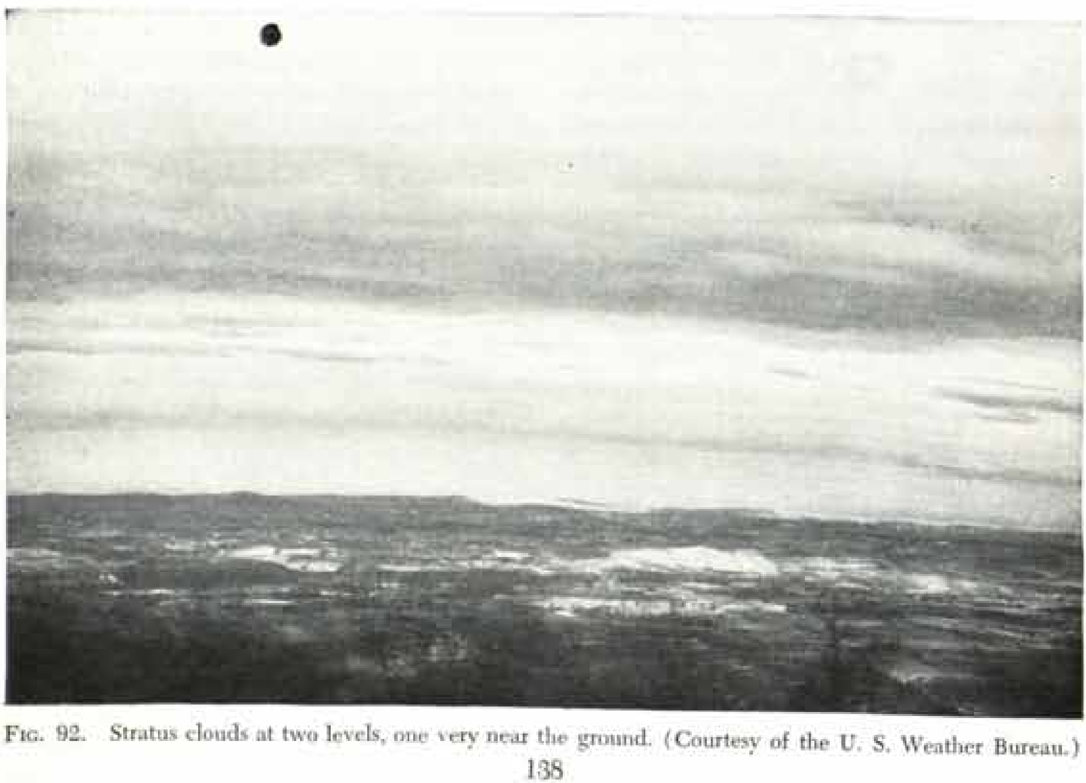


FIG. 92. Stratus clouds at two levels, one very near the ground. (Courtesy of the U. S. Weather Bureau.)

FIG. 93. Cirrus clouds, tufted form. (Courtesy of the U. S. Weather Bureau.)

condition. Transitional cloud forms are named by using one of the preceding cloud names, or some term such as "fracto," broken, or "nimbo," rain-bearing, as an adjective, and one of the cloud names as a noun. Thus we have strato-cumulus, cumulo-stratus, cirro-cumulus, fracto-stratus, nimbo-stratus, and other similar descriptive designations of the intermediate or transitional cloud forms.

Clouds are of great importance, for they are the immediate source of precipitation. They likewise affect man by being a factor in determining the percentage of the possible hours of sunshine, thereby limiting crop systems and crop yields. They also affect the amount of artificial illumination necessary, and man's productive capacity. They may even decrease the attractiveness of an area, for few people prefer a region characterized by much cloudy, gloomy weather. Possibly even the reputed dourness and taciturnity of certain population groups may be a reflection of the weather conditions of their home area, as is believed by some "authorities."

Precipitation. Precipitation, or deposition of water in either liquid or solid form, results from cooling the air in some manner. This may occur either near the ground or aloft. In the latter case, water particles lost by the air at some distance of the earth's surface become of such size, either from accretion by continued condensation or by coalescence, that they will not remain in suspension to form cloud or fog.

Four important aspects or characteristics of precipitation are: (1) form, (2) intensity, (3) distribution, and (4) amount. Lack of information concerning any one of these four characteristics of the precipitation of a given area may lead to an erroneous conclusion regarding the desirability of the precipitation of that area.

Form of Precipitation. Precipitation may occur as dew or frost, rain, sleet, hail, or snow, the exact form varying with temperature, place, and other conditions associated with the lowering of temperature.

Dew or frost will occur when the air immediately above the surface of the ground becomes saturated with water. Under such conditions, water taken up from the soil by plants and given off by their leaves or other evaporating surfaces is not absorbed by the air and therefore

accumulates on the plants. In this case, the source of the water is the soil. Under other conditions, the dew may represent water condensed from the air immediately in contact with the ground, and, under exceptional conditions, from a layer not to exceed 3 or 4 feet in thickness. The "gently falling dew" is a figure of speech. If temperatures remain above 32° F., this precipitation will be in the form of dew; if below 32° F., frost, which is not frozen dew but a direct deposition of water in solid or crystalline form. Dew and frost are more apt to occur on clear, quiet nights than when there is a wind or the sky is cloudy, the latter conditions tending to prevent cooling of the surface air to the dew point. As has been noted in an earlier chapter, certain methods of preventing frost are based upon the fact that checking too rapid radiation will be effective in preventing cooling and condensation of water.

Rain occurs when the temperature of the air at some elevation above the ground is lowered sufficiently to produce precipitation of water in a liquid form. This may result from cooling in ascending convection currents; from lowering of temperature by the forced ascent of air over major topographic irregularities; or by cooling resulting from importation from higher latitudes of large masses of colder air which force warm surface air aloft, thus lowering its temperature and producing condensation of water. The first of these two causes produces local storms or thunderstorms; the latter two, more general rains. Heavy and protracted rains can occur only with a continued renewal of the water supply and a continuation of the cooling. This becomes evi-

FIG. 94. Just as the year 1943 was drawing to a close, a severe sleet storm struck southern New England, with Connecticut and Massachusetts hit worst. Telephone and telegraph wires, swelled with ice to the thickness of a man's wrist, broke and disrupted service. Pavements were covered with sheets of glare ice and blocked by fallen branches and toppled poles. Electric wires fell down, halting work in factories and stopping oil-burning furnaces, thus forcing an unwanted saving of fuel. It was even reported that "the sudden ice froze barnyard birds fast in their tracks." In the scene above, the lovely elms which lent attraction to the streets of Litchfield, Connecticut, have literally been stripped limb from limb. (Courtesy of R. A. Benson, Jr.)

FIG. 95. Tobacco destroyed by hail. Most of the leaves have been stripped off completely; those that remain have been slit so badly that they are valueless. (Courtesy of the Rain and Hail Insurance Bureau.)

dent when it is appreciated that 1 inch of rainfall represents a fall of 72,300 tons of water to the square mile, or over 19,000,000,000 tons for a state the size of Texas. Attempts to produce conditions which will cause precipitation of such enormous amounts of water by artificial means are futile; only the enormous forces of nature are competent to ensure such results. Under exceptional conditions, and with certain types of clouds, precipitation may be induced by "sowing" the cloud with dry ice. At the present time, this method of producing precipitation is in the experimental stage, and its future practical value remains to be proved. In general, it is still true that "rainmakers" obtain a following only because many people will apparently believe anything provided it is sufficiently incredible. Rain is beneficial to vegetation and therefore to man, except as it may occur during the flowering or fruiting season. Therefore regions of abundant but not excessive rainfall are in general areas of attraction to man.

Sleet, in a restricted use of the term, is precipitation which occurs in the form of ice particles; in popular usage, it also includes rain which falls and solidifies on trees, pavements, and other cold surfaces when lower air temperatures are below freezing. Sleet storms introduce danger in traffic, the film of ice on road surfaces making driving hazardous. They also cause much property damage, the weight of the accumulated load of ice often stripping trees of their branches, thus ruining orchards. Similarly, the load of ice on wires may disrupt telephone and telegraph service, and even block highways when the ice-laden wires pull down the supporting poles. Fortunately, these storms are confined to the colder months of the year, hence they do not damage crops.

Hailstorms occur when precipitation is in the

form of globular masses, apparently of ice, but in reality made up of concentric layers of compact snow and clear ice, which fall only at times of thunderstorms, their formation resulting from extreme turbulence within the cloud mass where they originate. In the process of formation, the individual hailstone alternately rises and falls, carried aloft by ascending air currents, falling in response to the pull of gravity. With each upward movement, it acquires an additional layer of snow or ice, thus increasing in size until finally it becomes so large that it falls to the ground. Hailstones ½ inch in diameter are relatively common; some with diameters of between 4 and 5 inches have fallen at times of great atmospheric disturbance. Occurring as they do for the most part during the warm season, hailstorms cause an enormous loss, estimated to be in the neighborhood of $100,000,000 annually for the United States, and about $4,500,000 for Iowa alone. In a single storm of this type which occurred at Albert Lea, Minnesota, in May, 1945, some of the hailstones were the size of eggs. Windows were broken; many of the streets of the business section were so littered with glass that vehicular traffic was interrupted for several hours; not a roof in town escaped damage. Fruit trees were stripped of blossoms and bark; 15 per cent or more of the crops of the surrounding farming area were destroyed. Even birds were killed in considerable numbers. In all, the damage by this one storm totaled approximately $1,000,000, an amount exceeded in numerous instances.

Though hailstorms cause considerable property loss in towns, the major damage is to crops. Corn is stripped of its leaves and killed; cotton is ruined in similar fashion. With a crop such as tobacco, the leaves of which are marketed, loss is often complete. Even fruit crops do not escape, quite apart from damage to blossoms and trees, for hailstones often pit pears and other tree fruits so badly that they are unsalable and cause even greater damage to strawberries and tomatoes. Fortunately, many of the more severe hailstorms occur in the drier, less desirable agricul-

FIG. 96. Winter travel in northwestern Siberia, in the Nenets national district of the U.S.S.R. During the winter months, when the ground is frozen and snow-covered, travel across country by reindeer-drawn sledges is possible, even without good roads. (Courtesy of Sovfoto.)

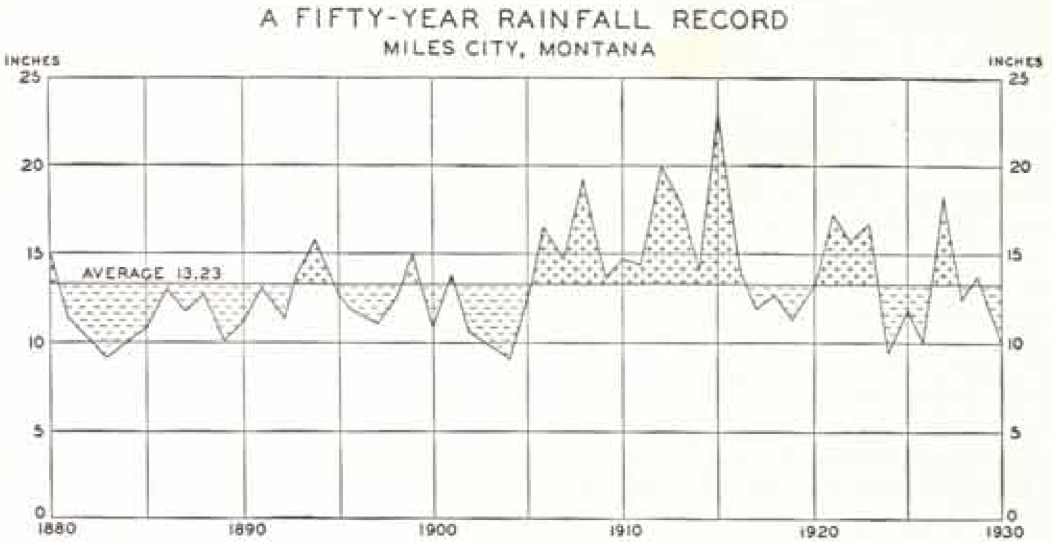


FIG. 97. This 50-year rainfall record shows alternate wet and dry periods, but the length of these varies so greatly and irregularly that the probable amount of rainfall in a given year is unpredictable. This imposes a handicap on agriculture, for it introduces too much uncertainty to permit intelligent planning of production. (After the U. S. Weather Bureau.)

tural areas of the Great Plains, as in western Kansas, where the type of storm with which hail is associated is not uncommon.

Precipitation at temperatures below freezing is commonly snow, a crystalline form of water. As has been noted earlier, when temperatures are low, snowfall is never heavy, but light snow has been known to fall at −52° F. Therefore it is never "too cold to snow," but only too cold for heavy snowfall. Snow is generally beneficial, forming a blanket which protects the ground and plants from sudden and great changes in temperature, thus preventing winterkilling of grass and crops. When it falls in mountain areas in which streams head, melting of the snow supplies water to the rivers during the spring and summer, thereby regulating their volume and increasing their desirability for various types of use. Snow likewise supplies an appreciable amount of water for crops in agricultural areas, provided runoff is not too rapid. Snow also makes heavy hauling practicable where roads are normally poor. In large urban centers such as New York City, however, heavy snowfalls impede traffic and entail much expense for their removal, in which respects they are detrimental.

Intensity of Precipitation. Precipitation varies with respect to intensity from a mist, in which the minute drops of water measure only 0.004 of an inch in diameter, to violent thunderstorm downpours, with raindrops 0.2 of an inch in diameter, with all gradations between these two extremes, neither of which is as beneficial as showers of moderate intensity. Too much mist creates an impression of too much rain, whereas this may not be true. An example of such a condition is afforded by the Seattle area, which has an average of 151 rainy days a year; a total annual precipitation of 34.03 inches, not an excessive amount; and an average precipitation of less than 0.23 inches during each rainy day. Such conditions limit crop production, not because precipitation is too great, but because the large number of rainy days affects agricultural potentialities adversely by decreasing the amount of sunshine. By contrast, at Opid's Camp, in the Big Santa Anita Canyon, southern California, over 1.02 inches of rain fell in 1 minute in April, 1926; in the Cherrapunji Valley of northeastern India, 42 inches of rain have fallen in one day. Such torrential downpours cause much damage.

In the oases of dry areas, where water for crops

AVERAGE MONTHLY PRECIPITATION IN INCHES

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Sacramento	3.7	3.0	2.6	1.5	0.8	0.1	0.0	0.0	0.4	0.09	1.9	3.0	17.9
Bismarck	0.45	0.44	0.89	1.52	2.32	3.35	2.35	1.82	1.23	0.094	0.57	0.57	16.34

is not supplied by local rainfall except in small part, but is drawn from wells, springs, or rivers, and where violent rains are the usual type, the damage they cause is so great that the inhabitants of such areas are reported to pray that it will not rain. Desirable intensities of precipitation lie between the two extremes; the optimum would be the heaviest fall within a given time which could be absorbed effectively by the soil, without objectionable runoff.

Distribution of Precipitation. Both the time and regularity of occurrence of the precipitation of an area are important to all life forms, including man. Precipitation is most beneficial when it occurs during the season of plant growth; least when it occurs during the colder months of the year, when water requirements of plants are small or when plant growth ceases. Inspection of the accompanying tabulation of the precipitation of two places with approximately the same amount of rainfall will show a marked difference in distribution with reference to the frost-free season, with a consequent difference of effectiveness in crop production. Sacramento, California, receives 84.3 per cent of its precipitation during the cold season, October to March inclusive; Bismarck, North Dakota, 76.3 per cent during the warm season, April to September inclusive. The latter place, therefore, is favored by comparison with Sacramento in respect to distribution of precipitation with reference to the frost-free season.

Regularity of occurrence, both from year to year and in time of occurrence within the year, is important. Where rainfall varies greatly in amount from year to year, or in time of occurrence within the year, the departure from the average is often so great that no basis for intelligent planning is available. At Miles City, Montana, for example, the average precipitation for the 50-year period ending in 1930 was 13.23 inches, probably ample for the production of certain crops in view of the latitude and the rate

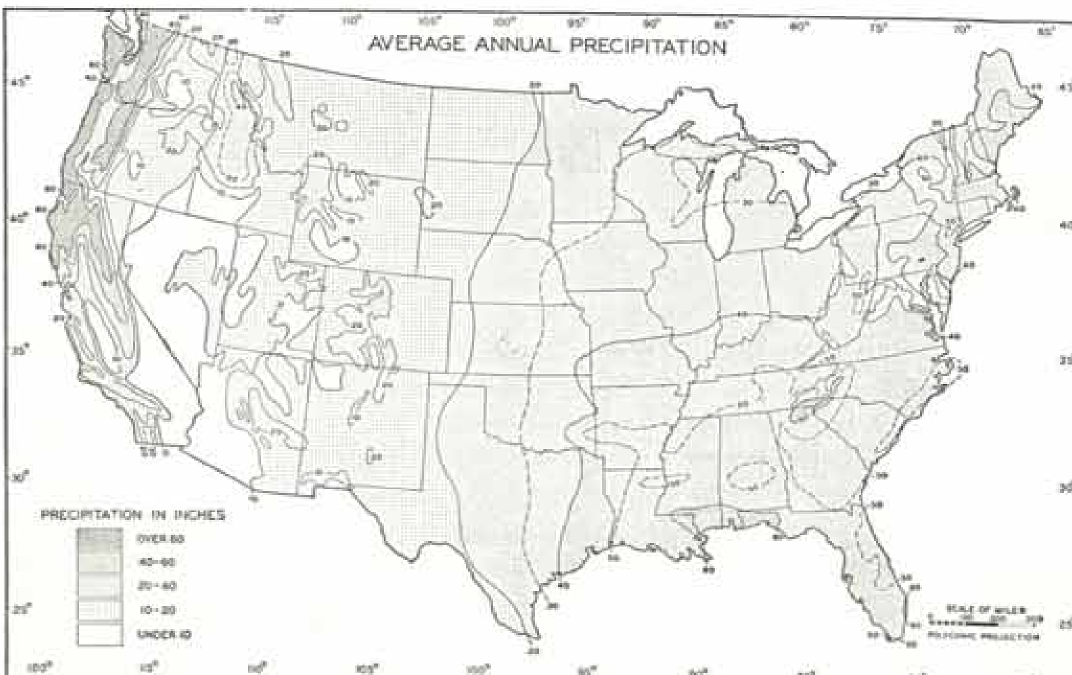


FIG. 98. Average annual precipitation for the United States. (After the Atlas of American Agriculture.)

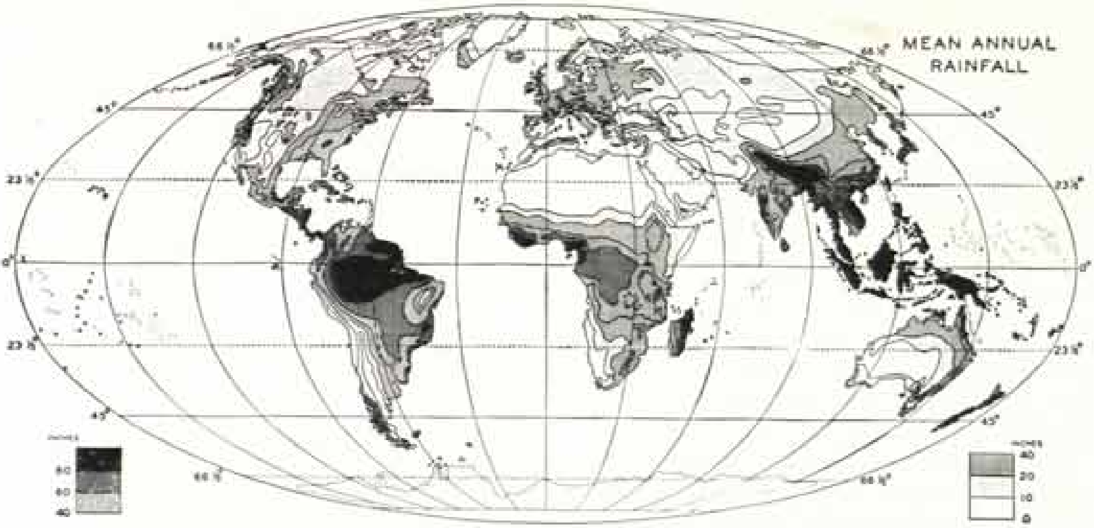


FIG. 99. Average annual precipitation for the world. (After various sources.)

of evaporation. However, inspection of the record, Fig. 97, shows that this amount was not received in any single year; actual amounts received varied from less than 9 inches, too little to grow crops successfully, to nearly 23 inches, considerably more than necessary. Further, there was no regularity in this departure from the average. Series of dry and wet years alternated, it is true, but without uniformity in length. Under such conditions agriculture becomes hazardous, for losses in dry years too often more than offset the profits of those years when rainfall is ample. It is this lack of dependability of total precipitation which introduces the major gamble into agriculture in much of the Great Plains region.

Amount of Precipitation. The amount of precipitation is variable, not only for a given place but likewise from place to place on the earth's surface, being affected by latitude, distance from the sea, prevailing wind direction, ocean currents, and topography. In general, the precipitation of low latitudes is greater than that of high latitudes; and that of coastal regions exceeds that of continental interiors, far from the ocean, the ultimate source of all our rain. Wind direction influences the amount, for onshore winds are moisture-laden; offshore winds are normally low in water content. Warm alongshore ocean currents tend to increase precipitation by affording a supply of warm, moisture-laden air which, on cooling over land, will lose water; cold currents, on the contrary, tend to decrease precipitation over the land, the cold air over them being relatively low in water content. Topographic conditions affect precipitation by causing ascending and descending air currents. When air rises over a mountain barrier, it is cooled and may lose water; when it descends, it is warmed and the air becomes drier. Thus the side of a highland barrier facing the direction from which the prevailing winds blow is generally well watered; the lee side is dry and said to be in the "rain shadow." For example, at Sacramento, in the Valley of California to the west of the Sierras and about 25 feet above sea level, the rainfall is about 18 inches; at Summit, Truckee Pass in the Sierras, at an elevation of approximately 8000 feet, 26 inches; and at Reno, to the east of the Sierras and in the rain shadow, only 6 inches. Some of the heaviest precipitation in the world occurs on the wet side of such topographic barriers in the tropics; some of the lightest known anywhere in the world in the rain shadow of these same barriers.

In parts of Central and South America, on the south slopes of the Himalayas, in parts of the East Indies, and along the Guinea Coast of Africa, all in the tropics, the average annual rainfall is in excess of 100 inches. In intermediate latitudes, the rainfall at elevations on west-facing coasts backed by highland barriers is likewise

very heavy, often ranging from 80 to 100 inches or more.

In such areas with heavy rainfall the following extremes of precipitation are noteworthy: Cherrapunji, India, with an average annual rainfall of 458 inches, but with 905 inches in the rainiest year; Mt. Waialeale, Kauai, in the Hawaiian islands, 451 inches; and Glenora, Oregon, 131 inches. Record falls of rain for one month include: Cherrapunji, India, 375 inches; Manoyuram, India, 264 inches; and Helen Mine, California, 71 inches. The heaviest rainfall of record for one day is 46 inches at Baguio in the Philippines, with that of 42 inches at Cherrapunji only slightly less.

At the other extreme, many desert areas are almost rainless. The average annual rainfall at Greenland Ranch, Death Valley, California, for example, is only 1.45 inches; that at Iquique, Chile, 0.6 inches; at Arica, also in the Atacama Desert, 0.02 inches. At Iquique, 14 years have been known to pass without rain, the average annual rainfall of 0.6 inches being the amount falling in one or more torrential downpours divided by the number of years of the record. In the Thar, in northwestern India, for example, 34 inches of water have fallen in two days in an area with an average annual rainfall of less than 5 inches.

Neither of the two extremes of amount of precipitation is beneficial to man, both handicapping his occupation of an area. The exact amount which will be the optimum varies with form, distribution, intensity, rate of evaporation, and other factors such as natural drainage and soil types. Thus a much smaller amount may be sufficient if it falls during the warm months in showers of moderate intensity, in an area with moisture-retentive soils where topographic conditions do not permit rapid runoff, in the higher latitudes where temperatures check evaporation, than would be satisfactory in lower latitudes with rapid evaporation and other conditions making for low effectiveness of the precipitation. In general, rainfalls of from 20 to 60 inches are advantageous. Below 20 inches, agriculture normally becomes hazardous; above 60 inches, the excess precipitation is not beneficial. Inspection of a population map of the world will show that at least 90 per cent of the world's inhabitants live in those areas favored by precipitation conditions.

QUESTIONS AND EXERCISES

1. What is a fog? How are fogs caused? How do they differ from clouds? Why is a rising fog an indicator of fair weather to follow? A falling fog one of probable bad weather to come?
2. Explain the cause of the summer fogs on the coast of California. What is the source of the water condensed to form these fogs?
3. Why are fogs more prevalent in depressions and during the winter months than on hillsides and during the summer?
4. In what parts of the world are fogs both dense and frequent? In what parts of the United States? What causes the fogs in each of these areas? What is meant by a dense fog? How and in what respects do fogs handicap an area if they occur too frequently and are too dense?
5. How do clouds affect man?
6. Under what conditions will dew and frost occur? What are the possible sources of the water which accumulates in what is ordinarily known as "dew"?
7. What causes rain in nature? Why are attempts to produce extensive general rain by artificial means futile?
8. Why is precipitation in the form of sleet detrimental? What property damage results from sleet storms? During what season of the year do these storms occur?
9. How are hailstones formed? How large may they become? What damage do hailstorms cause? In connection with what kind of storms do hailstones fall?
10. What are the beneficial effects of precipitation in the form of snow? The detrimental effects?
11. What intensity of precipitation is most beneficial? Why are torrential downpours detrimental? Why do the inhabitants of oases in deserts pray that it will not rain?
12. What distribution of precipitation is most beneficial? How is California handicapped by precipitation distribution? How is North Dakota favored?
13. How does the precipitation of Montana in the vicinity of Miles City introduce a hazard into agriculture? Does the Miles City record support the popular belief in seven wet years followed by seven dry years? Why not?
14. With what factors does the amount of precipitation vary? How does each operate to affect the amount of precipitation? What is meant by

the term "rain shadow"? Why is the precipitation of Reno, Nevada, so light?

15. Under what conditions will areas have maximum precipitation? Name and locate several places with very heavy precipitation, and state the amount for each. If possible, explain the cause for the heavy precipitation of each of these areas.
16. What is the heaviest precipitation of record for one month? For one day? Where did these precipitations occur? Why in the tropics? Why so heavy in each case? How do these amounts compare with the record precipitation of your home area for a month? For a day?
17. What are some of the minimum annual precipitations of record? What is the distribution of precipitation in such areas with very light precipitation? What is the intensity of precipitation in such areas?
18. What relationship does population distribution bear to the amount and effectiveness of precipitation? Illustrate by examples.

SELECTED REFERENCES

Blair, T. A., *Weather Elements*, Prentice-Hall, Inc., New York, 1937, Chap. V.

This chapter deals with condensation of water in the atmosphere, and the various forms assumed.

Kendrew, W. G., *Climate*, Oxford University Press, London, 1930, Chaps. XXIII, XXIV, XXV, XXVI, XXXIV, XXXV, and XXXVI.

In the several chapters suggested for reading, the causes of rain are discussed in Chap. XXIII; the distribution and regions of rainfall in Chap. XXIV; snow in Chap. XXV; sleet in Chap. XXVI; and fogs in Chaps. XXXIV, XXXV, and XXXVI. This will be found to be a very useful reference, with treatment of the topics sufficiently complete, and both clear and interesting.

Trewartha, G. T., *An Introduction to Weather and Climate*, McGraw-Hill Book Company, Inc., New York, 1943, pp. 149–188.

The pages cited discuss condensation and precipitation. If additional reading on these topics is desired, a list of references will be found at the end of the chapter.

Ward, R. D., *The Climates of the United States*, Ginn and Company, Boston, 1925, Chaps. X and XI.

These two chapters are devoted to a rather detailed discussion of some characteristics of rainfall and snowfall, with particular reference to the United States, to which the discussion of all climatic elements is limited, as indicated by the title.

Chapter Fourteen

CLIMATIC ELEMENTS: WINDS

Winds, Their Characteristics and Cause. A wind is air in horizontal or approximately horizontal motion in the lower atmosphere; with either ascending or descending currents, the air is calm. Such horizontal movement results from pressure differences associated with variations in temperature, flow of the air being from an area of higher to one of lower pressure.

Winds are named according to the direction from which they blow. Thus a north wind is one from the north; a south wind, one from the south. Wind direction is registered by a weather vane, the arrow of which points into the wind, or in the direction from which the wind comes. The strength of the wind, which is measured by the anemometer, increases with pressure differences and altitude. Therefore winds are strong at times of considerable pressure differences, and often violent near mountain summits. The United States Weather Bureau forecasts classify winds with velocities of 12 miles per hour or less as light to gentle; of from 13 to 24 miles per hour inclusive as moderate to fresh; of from 25 to 38 miles per hour as strong. Above 38, but not exceeding 75 miles per hour, winds are of gale strength; above the latter velocity, they are described as of hurricane intensity.

The total mass of the atmosphere is estimated to exceed 5 quadrillion tons. To move this vast amount of air, keep it in motion, and produce winds requires an enormous amount of energy. This is supplied primarily by the sun and gravitation, with heat liberated by condensation of water producing much of the upward convection; rotation of the earth and centrifugal force causing modification of the direction of horizontal motion.

Winds and Man. Winds are of importance to man in that they affect his comfort, his health, his activities and their success. By their effect on rate of evaporation and sensible temperatures, they modify the habitability and health conditions of a region. If they blow from higher latitudes or colder regions, they import low temperatures; if from over warm lands or the tropics, they cause temperatures to rise. In either case, the effect on human comfort is marked. Winds are also carriers of large amounts of moisture if they blow from over bodies of water, particularly if the water is warm; they are drier if they come from over extensive, arid land areas. Thus they affect both temperature and precipitation, and thereby man's economic activities and their returns.

The General Air Circulation. Though extremely complex in detail, the larger features of the earth's air movement assume a relatively simple and coherent pattern related to zones of pressure which shift but slightly with the changing seasons. This pattern is shown diagrammatically in Fig. 100 and, somewhat generalized but more accurately, in Fig. 101.

Low- and High-pressure Belts. Encircling the earth at the equator is a belt of low pressure resulting from continuously high temperatures. In this area, known as the "belt of equatorial calms" or the "doldrum belt," ascending air currents are the rule and winds are either lacking or they are light and variable in direction. Because of these ascending currents of warm, moisture-laden air, precipitation is adequate and commonly heavy in the doldrum belt for, as air rises, it is cooled and frequent convectional rains or thunderstorms result. (See Figs. 99 and 101.)

Paralleling the equator, about 35° North and 30° South latitude, are two irregular belts where barometric pressures exceed 30 inches. These

belts, which extend considerably beyond the tropics, especially in the Northern Hemisphere, are known as the "subtropical highs," or the "horse latitudes." In them, the air is believed to be descending from aloft, which causes calms. As the air descends, it is heated by compression, which increases its ability to hold water. Therefore precipitation is generally light in the areas where subtropical highs prevail. (See Figs. 99 and 101.)

Still farther poleward, about 65° North and 65° South latitude respectively, belts of low pressure known as the "subpolar lows" encircle the earth. These belts are continuous over the southern oceans, but interrupted over the land masses of northern high latitudes.

At and near the poles, pressures are continuously high over the continental glaciers of the Arctic and Antarctic. In both the subpolar lows and near the poles, where high pressures prevail, precipitation is light, for the air is cold and can hold very little moisture. (See Figs. 99 and 101.)

Winds of the General Circulation. Between the doldrums and the subtropical highs, winds known as the "trades" blow equatorward from the northeast in the Northern, and the southeast in the Southern Hemisphere, the easterly component in their direction resulting from the deflective influence of the earth's rotation. Where best developed in the eastern portions of the great oceans, they blow both steadily and continuously, with velocities of from 10 to 15 miles per hour; over land masses, this regularity is interrupted. The trades bring heavy precipitation to windward coasts, or those toward which they blow, if these coasts are backed by highlands of considerable elevation. Some such regions, indeed, are among the rainiest in the world. By contrast, most inland areas and all lee coasts where trade winds blow are semiarid or arid. (See Figs. 99 and 101.) Over the oceans, these winds were effective in determining trade routes in the days of sailing ships; on the land, they mitigate high sensible temperatures on the coasts toward which they blow, thereby serving as one factor in determining the preferred location of tropical plantations.

The "westerlies," winds which blow between the subtropical highs and the subpolar lows, are deflected increasingly with increase of latitude, so that they vary from southwest to west with

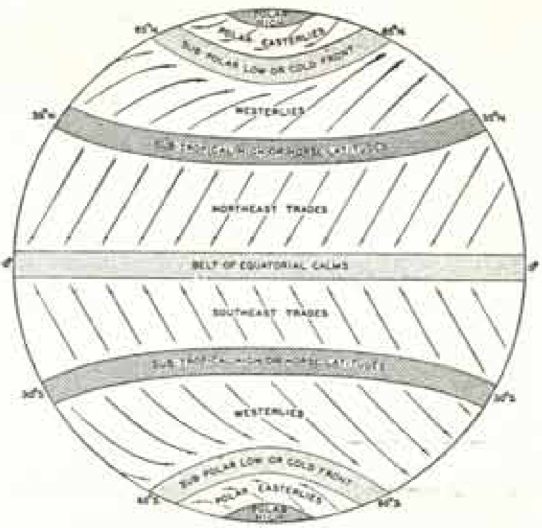


Fig. 100. Diagrammatic representation of the general air circulation, showing belts of high and low pressure and wind belts.

distance from the equator. At sea level and over the land these winds are subject to many interruptions, but at elevations of from 5 to 6 miles and over the oceans they blow more regularly. In the Southern Hemisphere, where large land masses are lacking in intermediate latitudes, they are so strong and persistent that the latitudes in which they blow are known as the "roaring forties." Even in intermediate latitudes of the Northern Hemisphere they blow strongly and steadily enough to be important in air navigation. Within the belt of the westerlies, the amount of precipitation varies with latitude, topography, distance from the sea, and location with reference to the storm tracks. (See Figs. 98, 99, and 101.) Further discussion of these factors will be found later in this and in the following chapter, in the Appendix, and in the selected references, if additional information is desired.

In still higher latitudes, the winds which blow off the great continental glaciers of polar areas are deflected to the extent that they become easterly winds, known as the "polar easterlies." As with the westerlies, these winds are better developed and more regular in the Southern than in the Northern Hemisphere, where land masses cause interruptions. In these high latitudes, precipitation is everywhere light because of the low temperatures. (See Figs. 99 and 101.)

It will be noted that the polar easterlies meet

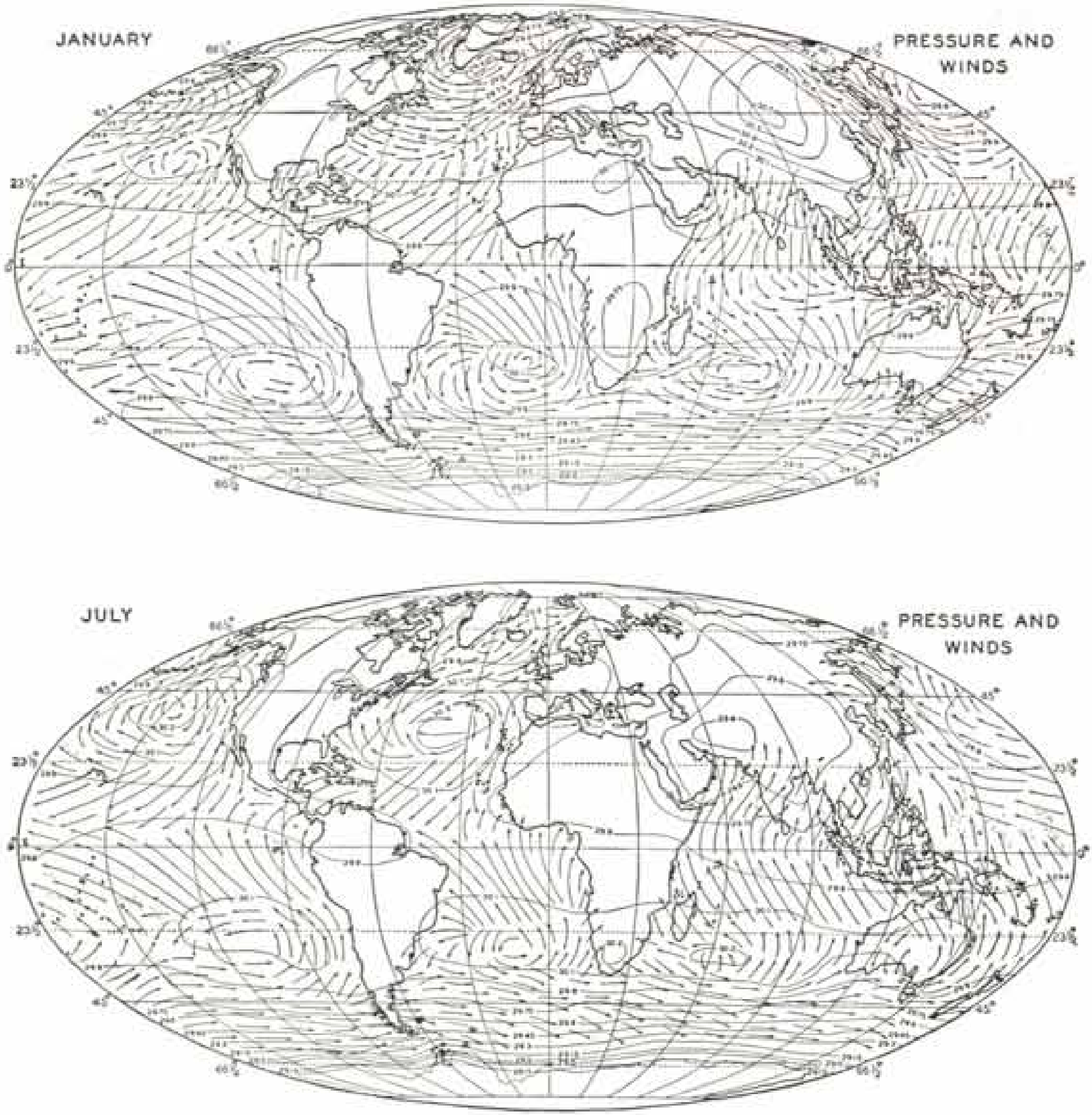


FIG. 101. Generalized pressures, January and July, and generalized air movements and winds over the oceans for the same months.

the westerlies in the belts of subpolar lows. This zone of contact is sometimes known as the "polar front." Since it is an irregular, changing boundary between cold and warm air masses, its shift may introduce large masses of cold air into intermediate or even lower latitudes. It is along this shifting polar front that most of our storms and weather originate.

On the average, pressure belts are centered along given parallels with prevailing winds blowing between them, but since the distribution of insolation changes with the seasons, the belts of pressure and winds shift, moving north during our summer and south during our winter months. (See Fig. 101.) One important effect of this migration is that a given place may be in one pressure or wind belt in winter, another in summer, which affects the distribution of precipitation. This is the case on the coast of California, which receives most of its rain during the winter

months, when moisture-laden westerly winds blow toward the land.

Periodic Local Winds. With certain relationships of land and water or of topographic conditions, winds which affect only limited areas may develop. These embrace land and sea breezes, mountain and valley breezes, and other "gravity" winds arising from air drainage induced by seasonal or other periodic changes of temperature.

Along seacoasts and the shores of large lakes, the difference between temperatures over land and water is pronounced, both in the afternoon during the hottest time of day and during the coldest time of day, shortly after sunrise. Such differences in temperature produce pressure inequalities which cause winds to spring up. In the heat of the day, this will result in a breeze from over the water, a sea or lake breeze; in the early morning, a land breeze. In both, only a shallow layer of air is affected and the breezes blow over only a narrow strip of land and water. Of the two, the lake or sea breeze is more important, for it lowers land temperatures during the hottest part of the day, whereas the land breeze serves only to prevent temperatures from falling as low as they would in its absence. Further, the land breeze is less well developed, temperature and pressure differences between land and water being less shortly after sunrise than later in the day. Along the Maine coast, the shores of the Great Lakes, and other similar resort areas, sea and lake breezes lower temperatures sufficiently so that their economic value is considerable.

Mountain and valley breezes result from differences in rapidity of nighttime cooling on slopes and in valleys, and accompanying slow movement of air down the slopes and collection in the valleys. When this flow gains some velocity, as in a narrow, steep-sided valley, heating by compression offsets cooling. This causes turbulence which, in combination with the flow, may prevent fall frosts on land located where the valley debouches on a flat-topped area or terrace, thus affording favored locations for orchards such as those in the vicinity of Salt Lake City.

"Gravity" or "fallwinds," induced by seasonal differences in radiation cooling in areas of considerable topographic diversity, are known on the coasts of Norway and on those of Greenland and the Antarctic continent, those of the latter often being violent. Locally, these winds have definite names. In the northern Adriatic, the cold northeast wind resulting from rapid radiation on the adjacent plateau of the interior in winter is known as the "bora"; a somewhat similar cold wind on the Mediterranean coast of France is the "mistral."

Monsoon Winds. Monsoon winds, convectional currents established in the atmosphere by seasonal differences in temperature between continents and adjacent oceans, resemble land and sea breezes in certain respects, but affect much larger areas. During the summer months, when temperatures are high and air pressure over the land is low, these winds blow from water to land, bringing rain. During the winter months they reverse their direction and blow from land to water, causing a dry season, for during the colder months temperatures are low and air pressure is high over the land, particularly over the interior of a great continent such as Asia. During the spring and fall months, when there is slight difference between land and water temperatures, winds in monsoon areas are light and variable in direction.

Monsoon winds are best developed in India and southeastern Asia, but they also occur far to the north, in China; to the south, in Australia; and on the coasts of Africa. In southeastern United States, the change from the prevailingly southerly winds of summer to the characteristically northerly winds of winter is a monsoon effect, important in determining climatic conditions.

The degree of development and the relative strength of the winds of the summer and winter monsoons are determined by the extent of the temperature differences at the two seasons. In India, the winds of the summer monsoon are strong; those of the winter, weak. In North China, the reverse is true. There, winter winds are strong and continuous for the interior of the continent is very cold; during the summer months, temperature and pressure differences between land and water are less pronounced and the winds are less highly developed and subject to interruptions.

In India, there is a complete reversal of wind direction with change from winter to summer months. During the winter months, pressures are high to the north, over the continent. Therefore cold, dry air then flows down the southern slopes of the Himalayas as northeasterly winds. At this

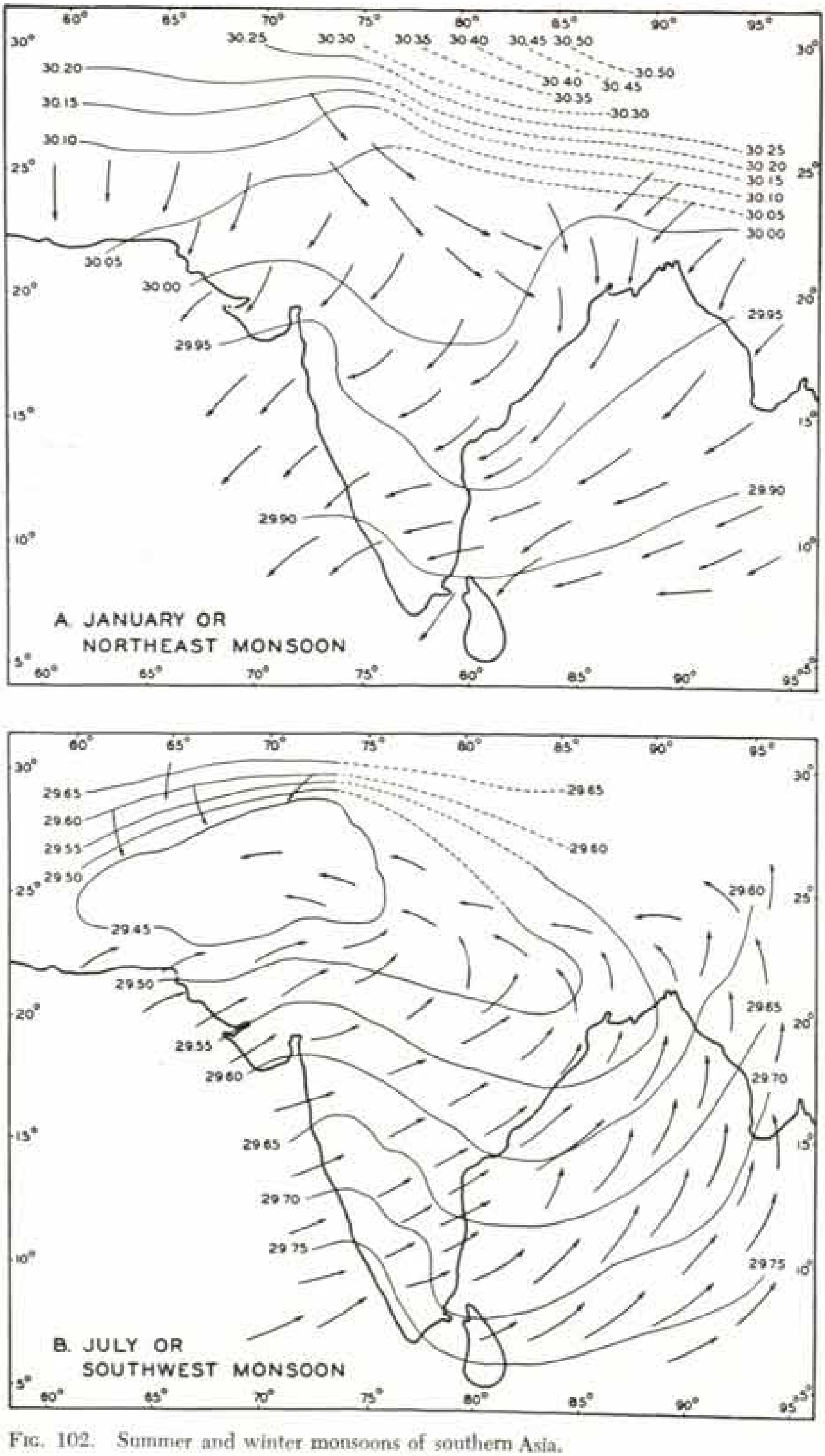


FIG. 102. Summer and winter monsoons of southern Asia.

time of the year, temperatures are generally moderate and little rain falls. During the summer months, the belt of high pressure is located to the south of the equator, over the southern Indian Ocean; the belt of low pressure over northwestern India. Therefore southwesterly winds blow from the sea to the land at this season, importing moisture-laden air and bringing much rain to India. It should be realized, of course, that the exact direction of the wind varies with the locality, though the movement of the air is always toward the land in summer and away from the land in winter. In the spring and fall, when pressures over the land and sea are much the same, the weather of India is very trying, for it is hot, winds are light and variable in direction, and the air is generally humid. Therefore sensible temperatures are high.

It will have been noted that, with monsoon winds, most of the rainfall is concentrated in the warmer months. Where precipitation is generally light, as it is in India, this summer maximum is of marked benefit. Similarly, the fact that the winds blow prevailingly toward the heated land of North China during the summer, causing as much as 90 per cent of the small amount of precipitation for the year to fall during the warmer months, is of great importance to the population of this dominantly agrarian area. The winters of North China are so dry, indeed, that the strong northwest winds of that season are dust-laden to an extent that they yearly add appreciably to the depth of the soil by deposit of their load of fine material.

The Secondary Circulation. In our latitudes, winds blow from all points of the compass: possibly one day from the east, the next from the north, and the following day from a westerly direction. It may seem, in fact, that there is no regularity in either the direction or the succession of directions, though in reality these winds and their sequence bear a definite relation to the pattern of the secondary circulation of the air in intermediate latitudes.

If a weather map showing barometric pressures and wind directions for a day is examined (see Appendix, Fig. 456), it will be noted that the isobars, or lines of equal barometric pressure, are roughly circular, elliptical, or oval in shape, and arranged concentrically around centers of low and high pressure, which represent local departures from the average in the region of the westerlies. It will further be noted that, in general, the winds blow toward the centers of low, and away from the centers of high pressure, with their exact courses affected by the deflec-

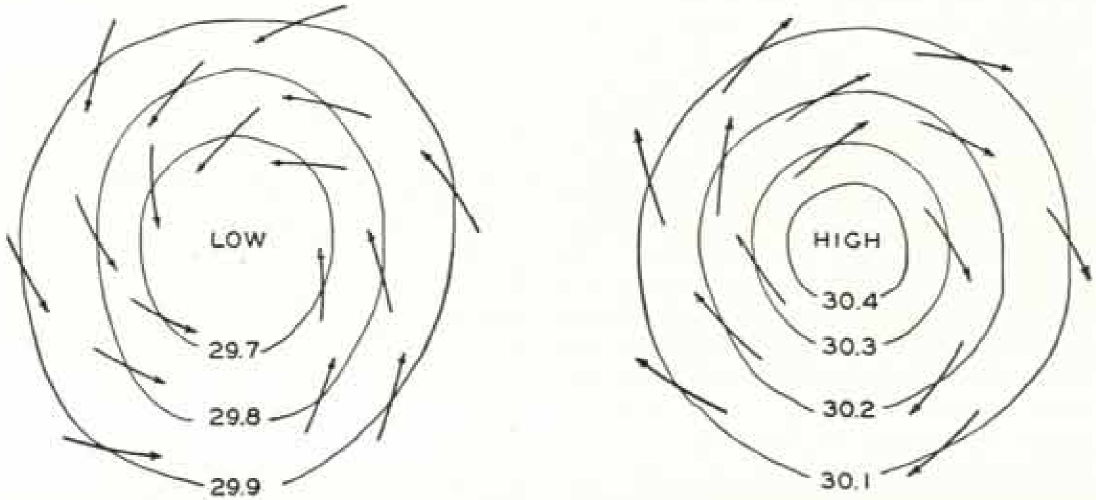


FIG. 103. Diagrammatic representation of pressures and wind directions associated with low- and high-pressure areas. The arrows indicating wind direction in the diagram at the left, that of a cyclone, show a rotary motion around the center of the low-pressure area, a result of the right hand deflection produced in the Northern Hemisphere by the earth's rotation. In the Southern Hemisphere, deflection is to the left, and the pattern would differ to correspond. The same deflective effect of the earth's rotation in the Northern Hemisphere is shown by the diagram for the high-pressure area; for the Southern Hemisphere, deflection would be to the left rather than the right.

tive influence of the earth's rotation and other factors of less importance. Thus the wind direction for a given place is determined mainly by the location of that place with reference to the centers of high and low pressure.

Cyclones or Low-pressure Areas. Low-pressure areas, or those where the barometer registers less than 30 inches, are known as "cyclones." Such "depressions" are roughly circular, elliptical, or oval in shape, and vary from 100 to more than 1000 miles in diameter, so that a single cyclone may cover a large fraction of the United States. Since winds blow toward or around this center, shown diagrammatically in Fig. 103, this results in southerly or warmer winds in the southeast half, and northerly or colder winds in the northwest half of such depressions in the United States. Higher temperatures, cloudiness, and precipitation are normally associated with the southeastern half of such depressions, a "hot wave" being only this "warm front" of a well-developed summer cyclone. During a hot wave, warm air is imported both day and night by the southerly winds which prevail; temperatures rise into the 90's or even to 100° F. or more in midafternoon; and sensible temperatures are high because of the excessive humidity. Even the nights are hot, for the importation of warm air continues and the high moisture content of the air prevents rapid radiation. Such hot waves cause much discomfort, interfere with effective work, and even cause deaths. They may likewise damage crops, often to the extent that the loss is greater than that occasioned by a severe hurricane.

Anticyclones or High-pressure Areas. Anticyclones, or high-pressure areas, like cyclones, are circular to elliptical in shape, but with the bounding isobars indicating pressures greater than 30 inches, a normal or average pressure at sea level. Frequently, they cover even more extensive areas than do cyclones. In them, the winds blow outward from the center as shown diagrammatically in Fig. 103. By contrast with cyclones, high-pressure areas are associated with low temperatures, light winds and calms, little cloudiness, and much clear weather. The coldest weather of our winters occurs during the calms at the centers, and on the southeastern margins of these disturbances, a "cold wave" being only the easterly front of a well-developed winter high-pressure area, or anticyclone. These typically American phenomena cause much inconvenience, suffering, and financial loss.

Destructive Winds. Most winds do not attain sufficient velocity to produce appreciable destruction of property or loss of life; their detrimental effects, if any, are limited to interference with human comfort, increasing the rate of evaporation objectionably, and others of similar character. Occasionally, however, winds become of such strength that they flatten crops, uproot trees, level buildings, and endanger life. The more important disturbances with which such violent winds are associated are the hurricane, or typhoon, and the tornado.

Tropical cyclones are vast whirls of air, 300 to 600 miles or more in diameter, and of convectional origin. Born over tropical seas, they travel westward in trade-wind areas, where they develop and do most of their damage. In the North Atlantic, they are known as "hurricanes"; in the West Pacific, as "typhoons"; elsewhere they may have local names, for example, "baguios" in the Philippines. In a well-developed hurricane, the pressure is below 28.5 inches, and it may drop to 27.5 inches or even lower. Around the center, or "eye," of the storm, the temperatures, pressures, winds, and cloudiness are arranged symmetrically, in which respects hurricanes differ from the cyclones of intermediate latitudes. At the center of the disturbance, the air is calm, but on its margins winds with estimated velocities of from 150 to 200 miles an hour blow inward toward the "eye," leveling all except the most substantially constructed buildings and piling up water and thus inundating low-lying shores.

These storms originate over the ocean, on the margins of the doldrums, and most often when this belt of calms approximates the poleward limit of its migrations. Therefore, though they may occur in any month of the year, they are most numerous in the summer and early fall, with September and October the months of normal maximum frequency in the Northern Hemisphere. As these storms move westward in the general drift of the trades, their paths curve to the right in the Northern Hemisphere, even into the region of the westerlies. When this occurs, hurricanes may ravage Florida and the Gulf Coast of the United States, and, at rare intervals, the Atlantic seaboard as far north as New England. The effects of such storms are both direct

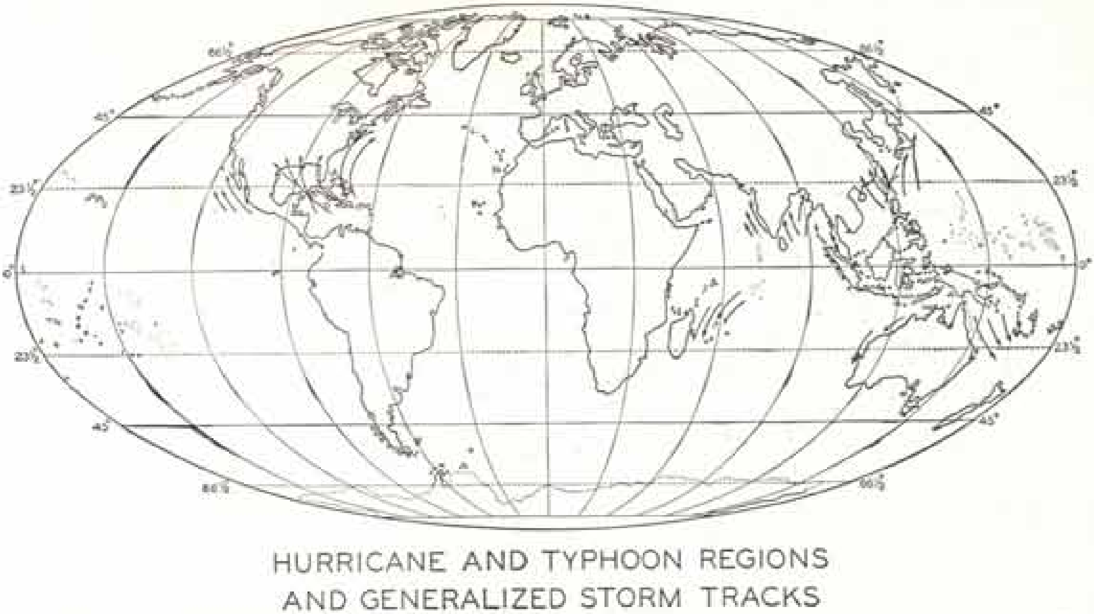


FIG. 104. Regions of occurrence and paths of tropical cyclones, known as hurricanes in the North Atlantic, typhoons in the western Pacific.

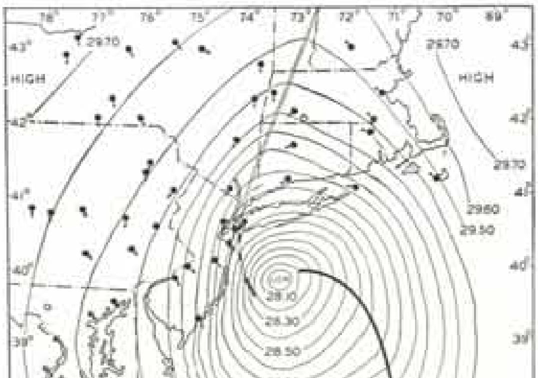


FIG. 105. The New England hurricane, September 21, 1938, 2:00 P.M., Central Standard Time, when the "eye" of the storm was south of Long Island. (After C. H. Pierce, Monthly Weather Review.)

and indirect. The direct effects are property damage and loss of life in the actual path of the hurricane; the indirect effect is disturbance of the normal circulation by introduction of a mass of warm air into intermediate latitudes. This affects both temperatures and precipitation, often beneficially.

By means of radioed reports from shipping and from local land stations the United States Weather Bureau plots the paths of hurricanes and determines the rapidity of their travel. This information is supplied to ship operators and others so that they normally have advance notice of the severity of the expected storm. This enables saving much life and property. Fortunately, such storms are not numerous, the areas affected are limited, and the destructive effects do not extend far inland. When they occur on Asiatic coasts with dense populations, however, they produce great property damage and loss of life. The typhoon which ravaged Tokyo and Yokohama in 1923, just after the great earthquake which leveled those cities, for example, is estimated to have caused 100,000 deaths and property damage of $1,000,000,000.

Tornadoes are rotating storms somewhat similar in appearance to the small dust whirls which travel down a hot pavement in summer, or the

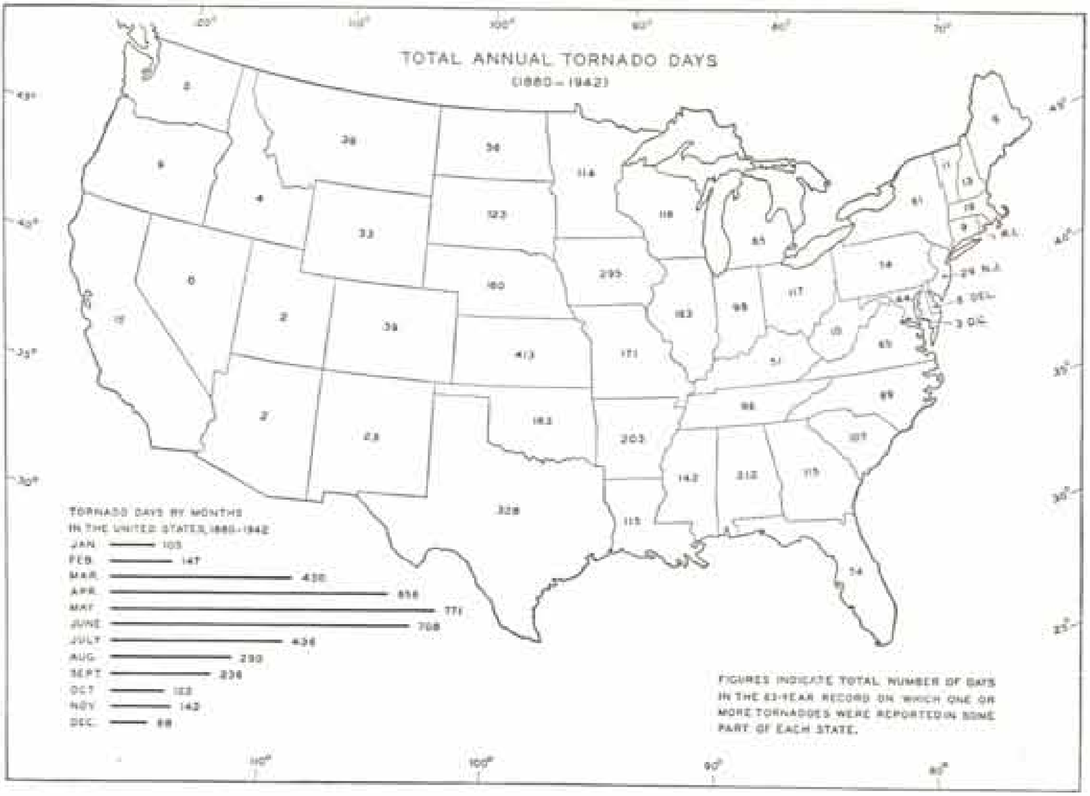


FIG. 106. Average tornado frequency in the United States. Even in the general area where tornadoes are most common, the Lower Mississippi Valley, their limited width and short paths of travel render the probability of their occurrence in any given locality slight. This is indicated by the comparatively low cost of windstorm insurance, which covers all wind damage. (After S. S. Visher.)

larger whirls which occur in deserts, as in Nevada on a hot day. They differ from such whirls, however, in both origin and relationship to low-pressure areas, though similar in most essential respects except size and wind velocity to tropical hurricanes. These typically American storms are accompanied by a funnel-shaped cloud composed of small drops of water. This funnel ascends and descends irregularly, harmlessly when some distance from the ground but, where touching the ground with its tip, causing great destruction, for wind velocities around it reach as much as 400 miles or more per hour. Wagons and other farm equipment, animals, and men are carried aloft, later to be dashed to the ground or dropped without harm. Over water, the tornado develops as a waterspout. Tornadoes occur during hot, sultry summer weather in the southern portion of well-developed cyclonic disturbances and travel in a general easterly direction until their force is dissipated, the path of destruction being very narrow and only a few miles in length. They are, in fact, special storms associated with the same weather conditions as thunderstorms.

Destruction by tornadoes results both from the violence of the winds and the explosive effect of the air confined within buildings, when the outside pressure is reduced as the storm passes. Fortunately, these storms are of relatively infrequent occurrence; in many areas they are virtually, or even totally, unknown. The regions of greatest tornado frequency are the Mississippi, the Ohio, and the Lower Missouri valleys, but even there the chance of occurrence of such a storm in any given locality is very slight. Thus the damage tornadoes produce, though locally important, is in the aggregate not large, the normal annual loss not exceeding $1,000,000, except in an occasional year such as 1896, when a tornado struck St. Louis.

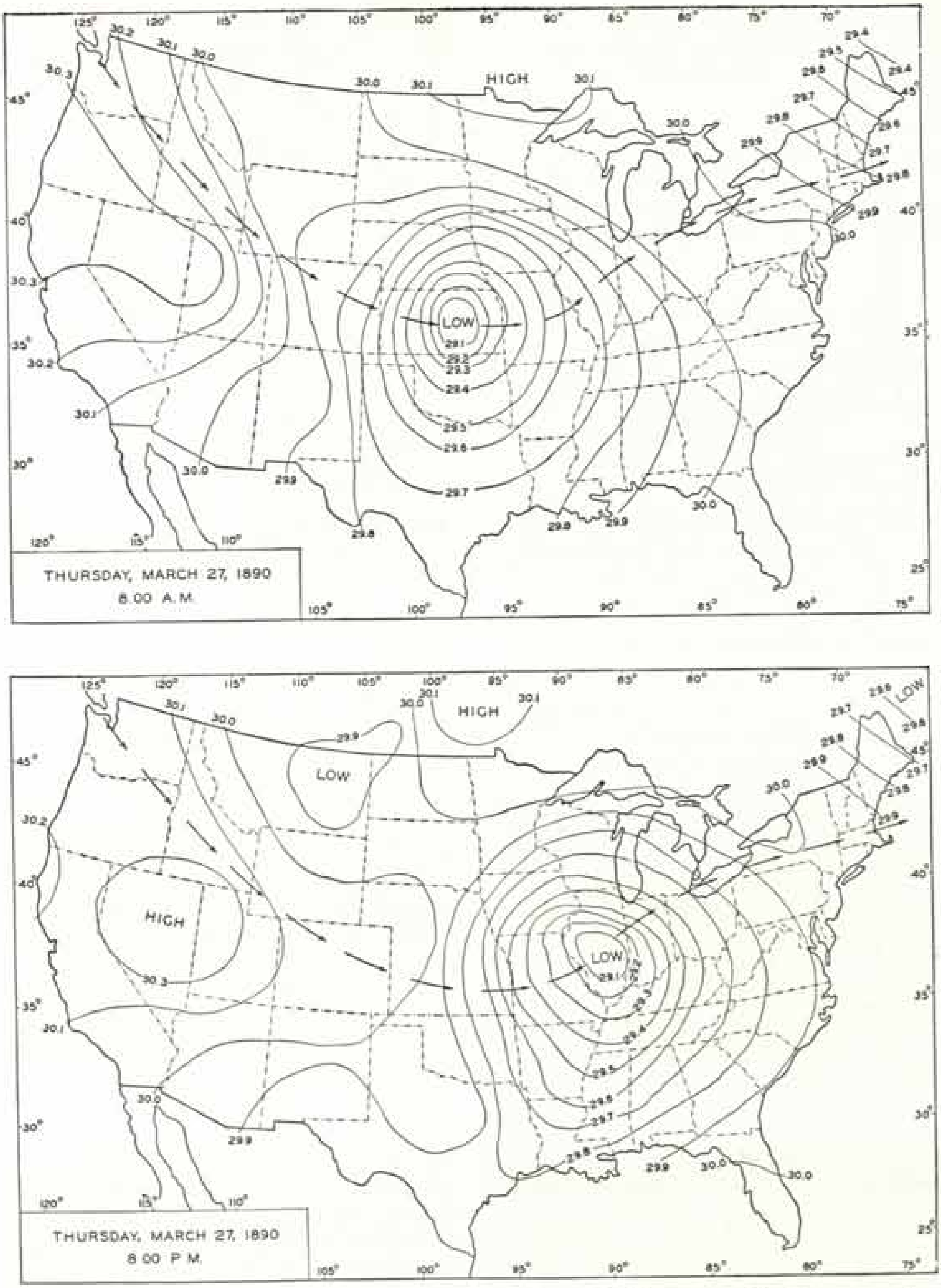


Fig. 107. Weather maps for the day of the Louisville tornado. (After the U. S. Weather Bureau maps.)

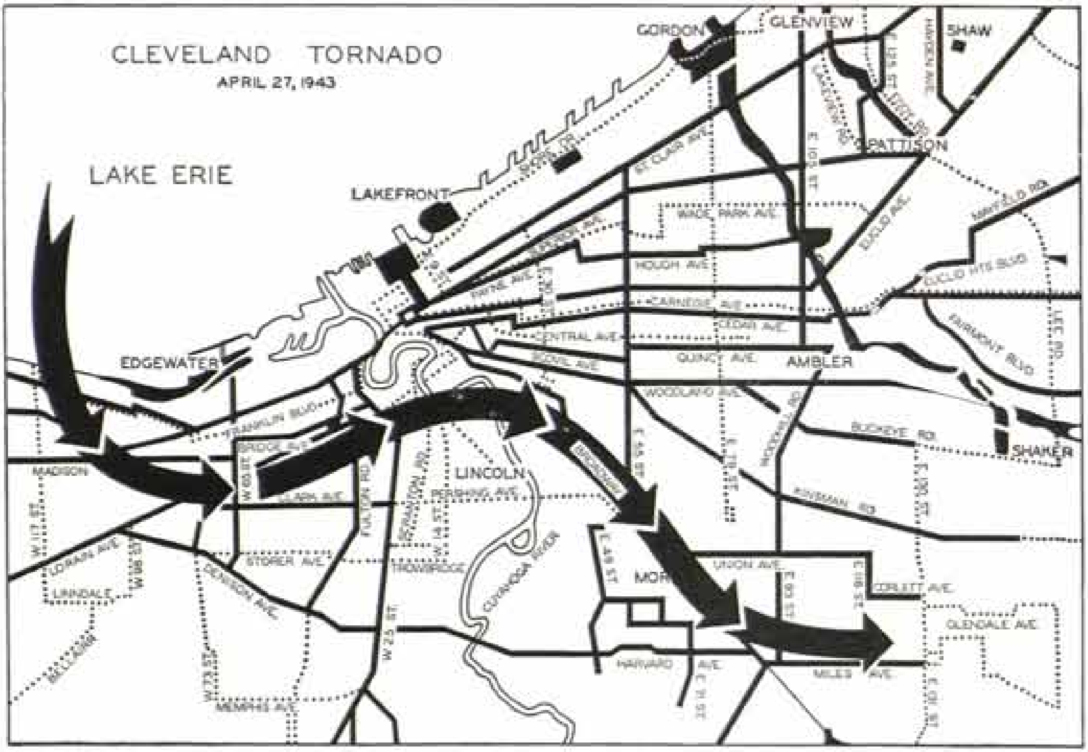


Fig. 108. Note the characteristic easterly path of the 1943 Cleveland tornado.

Fig. 109. Tornado damage. The appearance of the house would indicate that part of the damage resulted from the explosive effect of confined air. (Courtesy of the U. S. Weather Bureau.)

Special Local Winds. The "chinook" of the mountainous western United States and the equivalent "foehn" of the Alps are warm, dry winds, not uncommon in winter, blowing strongly down mountain slopes toward cyclonic centers, and thus warmed sufficiently as a result of compression by the overlying air so that their temperatures are sometimes as much as 40°F. or more above the seasonal average. These winds cause rapid removal of the snow cover by evaporation and melting, exposing the grass and therefore permitting pasturage of livestock during the winter months. Such removal of snow from the ground in the wheat-growing areas of the western states also makes early planting of spring wheat possible. This is advantageous since it permits considerable growth of the crop before the hot and often dry summer months.

Other warm and cold winds associated with cyclonic and anticyclonic disturbances often have special local names. Thus the "sirocco" is the warm south wind of Mediterranean areas from over the Sahara, and the "blizzard" is the

popular name for a northerly, snow-laden wind of high velocity in our western plains, though the term has neither definite meaning nor scientific usage.

QUESTIONS AND EXERCISES

1. Define the term "wind." Distinguish between winds and air currents. What causes winds? What instrument is used for measuring their velocity? What is the velocity of a strong wind in miles per hour? Of a destructive wind?
2. In what ways do winds affect man? Which are favorable? Unfavorable?
3. Describe the general circulation of the lower air, naming the winds and the belts of high and low pressure, and stating the latitudes of occurrence of each.
4. Where are the trade winds best developed? Why are they easterly winds? What are their beneficial effects? Remembering the route Columbus followed in making his discovery of the New World, how was he favored by winds?
5. Why are the westerlies better developed in the Southern than in the Northern Hemisphere? What are the "roaring forties"?
6. What causes shifts of pressure and wind belts? What is the direction of this shift in our summer? In our winter? What effect does this shift have on distribution of precipitation in certain areas?
7. Why is the sea breeze best developed in the middle of the afternoon? Why is the sea breeze more important than the land breeze?
8. How do mountain breezes sometimes prevent frost on adjacent flat-topped areas? What use has been made of this fact in the Salt Lake City area?
9. What is the "bora"? The "mistral"? Where do they occur and what is their cause?
10. During what months of the year does India receive most of its precipitation? Why? Is this beneficial or detrimental? Why?
11. What is a "cyclone"? Its size and atmospheric pressure? What is the relation of wind direction to the cyclonic center? What is a "hot wave"? How do hot waves affect man?
12. What is an "anticyclone"? Its size and normal atmospheric pressure? What is the relation of wind direction to the anticyclonic center? What is a "cold wave"?
13. What names are applied to tropical cyclones with high wind velocities? Where do such disturbances originate, what are their normal paths, and how do they cause property damage and loss of life?
14. What is a "tornado"? In what parts of the United States do tornadoes occur most frequently? Describe the characteristics of such storms, including wind velocity, path of travel, and damage produced. Explain how this damage is caused.
15. What is a "chinook"? What is the name of the equivalent wind in Switzerland? How are such winds caused? What are their characteristics? What beneficial effects do they produce?
16. Where do the "sirocco" and the "blizzard" occur? What are the characteristics of each? Are they beneficial or detrimental? In what respects?

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Blair, T. A., *Weather Elements*, Prentice-Hall, Inc., New York, 1937, Chaps. II, VI, VII, VIII.

The chapters cited consider different aspects of temperature, pressure, and winds, under the following chapter titles: Observing Temperature, Pressure, and Winds; Interrelationships of Temperature, Pressure, and Winds; The General Circulation; and The Secondary Circulation.

Kendrew, W. G., *The Climates of the Continents*, Oxford University Press, New York, 1928, Chap. XX.

This reference furnishes a detailed account of monsoon winds and a vivid description of the weather they bring to India.

Trewartha, G. T., *Introduction to Weather and Climate*, McGraw-Hill Book Company, Inc., New York, 1943, Chap. II.

The chapter recommended for reading is concerned with atmospheric pressure and winds. Additional references will be found at the end of the chapter.

Ward, R. D., *The Climates of the United States*, Ginn and Company, Boston, 1925, pp. 383-395; 359-380.

These pages afford a clear and standard discussion of hot and cold waves, sufficiently outstanding phenomena of our weather to justify additional consideration.

Chapter Fifteen

CLIMATIC ELEMENTS: WINDS AND THE WEATHER

The Earth's Atmosphere. The solid core of the earth is known as the "lithosphere," its cover of water as the "hydrosphere," and the continuous outer gaseous envelope as the "atmosphere." The exact thickness of this outer layer, the atmosphere, is indefinite, for the air grows thinner gradually with increasing distance from the earth's surface until it disappears for all practical purposes. Because of the compressibility of air, more than 50 per cent of the mass of the atmosphere is in its lower 3.6 miles, and 97 per cent is below the 18-mile level. Therefore the peaks of lofty mountains protrude into very thin air. This is one reason why their ascent proves difficult for man. Though most of the air is relatively near the earth's surface, twilight colors indicate that there is a considerable amount at a height of 40 miles, and the glowing of meteors proves that atmospheric gases exist at least 200 miles above the earth's solid crust.

Because of variations in characteristics produced by distance from the earth's surface, zones may be recognized in the atmosphere. These are: (1) the troposphere, the lower few miles where most of the mass of the atmosphere is concentrated; (2) the stratosphere, the immediately overlying stratum; and (3) the ionosphere, the uppermost layer, in which phenomena such as the northern lights occur. The plane of contact of the troposphere and stratosphere is known as the "tropopause."

The Troposphere. This layer of the atmosphere varies from 4 to 5 miles in depth at the poles to approximately 10 miles at the equator. In the lower atmosphere, or the troposphere, the air is greatly disturbed by currents resulting from heating; there is much water vapor and a great deal of dust; and there are many clouds. This stratum of the atmosphere is much warmer than the overlying layer, the stratosphere, for it is in contact with the ground, the direct source of most of the heat of the lower atmosphere. Because it is made up of dense air, contains many dust particles, and both gaseous and liquid water, it absorbs heat radiated from the earth effectively. As a result of the thorough mixing produced by convection currents, temperature distribution is regular, decreasing with elevation at an average rate of 3.3°F. for each 1000 feet of ascent. Variation from this rate, which changes with the time of day, the season, and location, is not great.

The Stratosphere. The stratosphere overlies the troposphere, beginning at a height of 4 to 5 miles at the poles, 6 to 7 miles midway between the poles and the equator, and at approximately 10 miles near the equator. It is in general a zone of uniform temperatures which are very low, ranging downward from –67°F. at 40 to 50 degrees of latitude to –112°F. near the equator. Only a small amount of water is present in the air at such low temperatures; there is little dust; and there are no clouds. Wind velocities, which attain their maximum in the upper troposphere, where friction is slight and important topographic obstacles are lacking, decrease markedly. The air is likewise very thin, and this fact, in combination with little air movement, favors air navigation. This is, however, handicapped to some extent by both temperatures and the low density of the air.

Winds and Weather in the Tropics. Winds bring the weather. When they blow from warmer regions, temperatures rise; when they come from colder areas, temperatures fall. Winds also affect precipitation, for, when dry, skies are clear and there is no rain; when moisture-laden, cloudy weather is probable and precipitation may occur. In view of the fact that the weather of each day

is a composite of temperature and moisture conditions, associated with wind direction and strength, it is obvious that a knowledge of air movement in the lower atmosphere is the key to an understanding of weather.

Knowledge of the air circulation of a given locality in the tropics as elsewhere is, then, necessary for an understanding of its weather. In considering the possibilities of tropical weather conditions, therefore, it is necessary to take into account the air movement in the doldrum belt and where the trade winds blow. In such areas, where interruptions of the prevailing winds or of the characteristic calms are not so numerous and important as in intermediate latitudes, the weather will vary but slightly from day to day, and often as well from month to month. Only as the wind belts shift, and not always even then, will a change of weather occur, for the shift may not be sufficient to produce such conditions as noted for India in the preceding chapter. Even where such change does occur, it is in precipitation rather than in temperature, for there is no cold season in the tropics; it is only hot part of the year and hotter the rest of the time at or near sea level. Where there is a seasonal distribution of precipitation, also, it may not be marked, and the drier part of the year may actually be rather rainy. This makes for a monotony of weather conditions which, though possibly pleasing for a time, may become rather trying, for man seems to work most efficiently in those parts of the world where diversity of weather is a common characteristic.

It is hot throughout the year in the doldrum belt, for the sun's rays are vertical or nearly vertical during all months. These high temperatures are responsible for the calms or light and variable winds characteristic of areas near the equator. In them, the air is rising, day after day. As it ascends, it cools; as it cools, it loses water, which frequently falls in the form of thunderstorm rains. Though it may not rain every day in any given place, for thunderstorms are local showers, it may rain every day somewhere in the vicinity, and the number of rains during a month in any place is extremely high. At Parà or Belém, near the mouth of the Amazon River, for example, the average number of rainy days in March, during the wetter season, is 28 out of a possible 31. Even in November, when it is relatively dry, it rains one day out of three. It is so rainy in Parà that it has been said: "No native can remember the day when it has not rained." Always it is humid, even when there is no rain, and sensible temperatures are high. These are conditions unfavorable for man; this is a repressive type of climate.

In those areas where trade winds blow day after day in the same direction, except as interrupted by infrequent tropical cyclones, the monotony of the weather is equally marked. If these winds blow from water *toward* the land, they import much moisture, which often falls in convectional showers, as in the doldrum belt. Day after day the weather is the same, although somewhat less trying than in the still lower latitudes of the belt of equatorial calms, for the amount of heat received from the sun varies somewhat during the year, and the winds lower sensible temperatures. In those areas where the trade winds blow *away* from the land, the air is dry; actual temperatures are high, often even higher than in the rainy trade-wind areas, because the sun beats down on the dry, unprotected soil and air temperatures become among the highest known. Sensible temperatures, however, may be quite tolerable, for evaporation is rapid. Still, these areas are undesirable for man because of their aridity. Therefore the trade-wind deserts, both north and south of the equator, are in general sparsely populated.

On the margins of the tropics, where the air is believed to be descending from aloft and consequently is being warmed by compression in the belts of subtropical highs, or the horse latitudes, aridity is likewise the rule, and semidesert to desert conditions prevail. Here, the weather may be rather pleasant, because seasonal range of temperature is appreciable; nights are cool even though days are hot; and sensible temperatures are generally moderate. Nevertheless, opportunity for man is limited by lack of water. Further, here as elsewhere in the tropics, though in lesser degree, the stimulating effect of frequent and considerable changes of temperature from week to week is lacking.

Winds and the Weather of Intermediate Latitudes. The weather of intermediate latitudes, by contrast with that of the tropics, is characterized by great variability. The popular expressions, a "spell of cold weather," and a "spell of warm weather," indicate general recognition of the fact that we live in latitudes with alternating periods of higher and lower temperatures. In the so-

FIG. 110. A simple type of mercurial barometer.

called "temperate zone," in fact, the weather is actually "intemperate." First it is warm; then it is cold; still later temperatures moderate. Further, the intensity of the heat, the severity of the cold, and the lengths of the individual periods of each are relatively unpredictable. In intermediate latitudes where we live, the fickleness of the weather is proverbial, and so great that it is used to illustrate the ultimate in undependability.

The Barometer and the Weather. We live at the bottom of a great "ocean" of air, much as do the forms of life which crawl on the sea floor, subject to the pressure of the overlying water. Upon each square inch of the body surface, therefore, rests a column of air many miles in length, and 1 square inch in cross section. At sea level, such a column of air would on the average weigh 14.7 pounds, or the pressure would be nearly 15 pounds to the square inch. On the average, also, as registered by a barometer, an instrument for measuring air pressure, it is said to be 29.92, or nearly 30 inches. This means that the pressure the air exerts at sea level is normally sufficient to support a mercury column nearly 30 inches in length in the tube of a mercurial barometer such as that shown in Fig. 110. In this instrument, a column of air many miles in length is balanced against a relatively short column of mercury, a heavy, liquid metal. In reading the instrument, the pressure is stated as the length of the mercury column the air is able to support. During a period of warm weather, the pressure decreases and the column shortens; with falling temperatures, the barometer "rises," or the column of mercury increases in length.

Since the inch is a unit of length and not of pressure, the United States Weather Bureau has, since January 1, 1940, indicated pressures on weather maps either in both inches and millibars, the latter a standard unit of pressure, or in millibars only. In this new system of numbering the isobars, or lines of equal pressure, 30 inches becomes 1015.0 millibars. Isobars are drawn at intervals of 3 millibars, about the equivalent of the 1/10 inch formerly used. Tables for the conversion of inches to millibars will be found in the Appendix, Chap. LIV.

From the readings of the barometer certain inferences may be drawn regarding the probable weather to follow, in accordance with the following rules formulated by the United States Weather Bureau. "When the wind sets in from points between south and southeast and the barometer falls steadily, a storm is approaching from the west or northwest and its center will pass near or north of the observer within 12 to 24 hours, with wind shifting to northwest by way of southwest and west. When the wind sets in from points between east and northeast and the barometer falls steadily, a storm is approaching from the south or southwest and its center will pass near or to the south or east of the observer within 24 hours, with wind shifting to northwest by way of north. The rapidity of the storm's approach and its intensity will be indicated by the rate and the amount of fall of the barometer."

Cyclones and Anticyclones. The characteristic spells of weather of intermediate latitudes are related to cyclones and anticyclones. The cyclone, a mass of warm air, brings lower pressures and

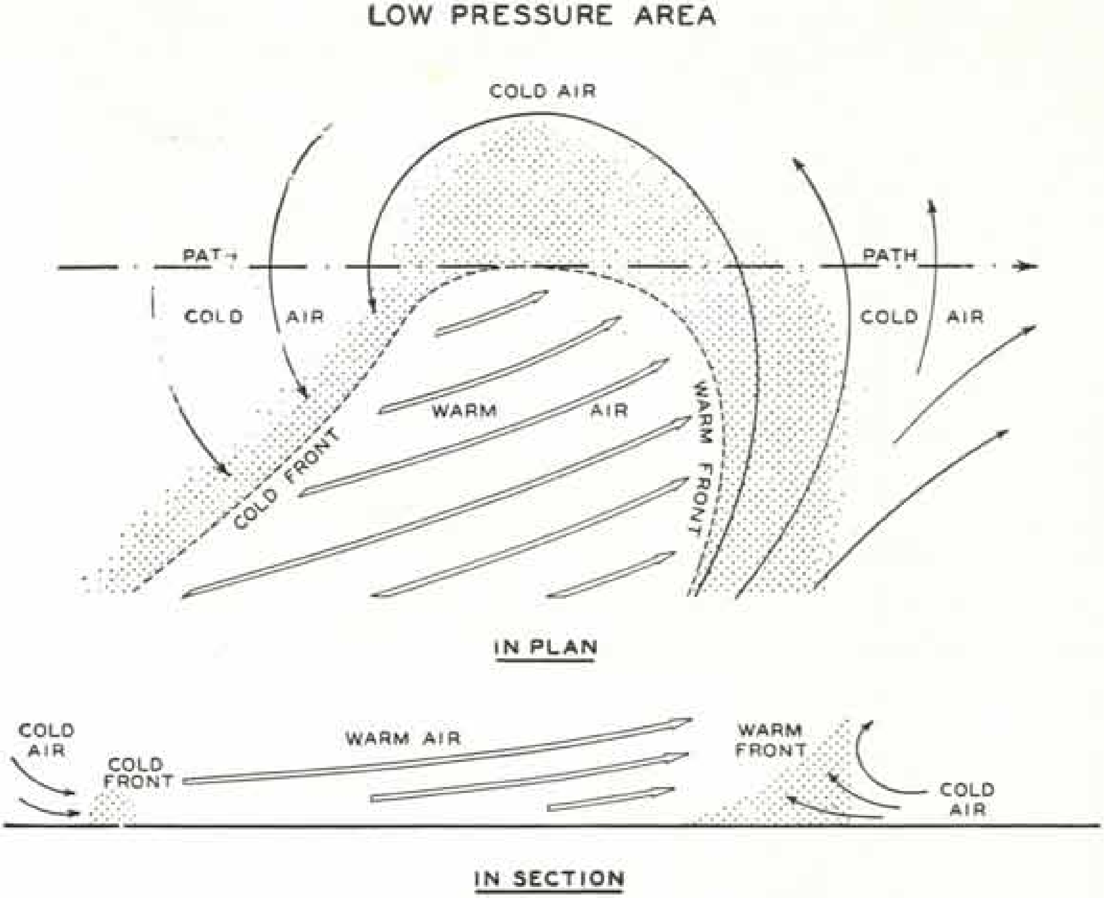

FIG. 111. Diagram of a cyclone, after Bjerknes. The stippling indicates cloud and precipitation. On the warm front, warm air "overrides," or is forced up over cold air. This causes cooling and probable cloud and precipitation. Along the cold front, cold air "underrides," or flows under warm air, forcing it aloft. This likewise causes cooling, probable cloud, and precipitation.

higher temperatures, or a warm spell; the anticyclone, a mass of cold, polar air, brings higher pressures and lower temperatures, or a cold spell. Study of the weather maps, Figs. 115 and 456, will disclose the relation between pressures and temperatures.

Origin and Paths of Travel of Cyclones and Anticyclones. Former views as to the origin of cyclones and anticyclones were based on the assumption that they were produced by convection currents, or that they were eddies resulting from surface irregularities or other causes. These views have today been displaced by the belief that they originate along the polar front, where masses of cold air from the polar regions meet masses of warm air from the tropics. Along this line of contact, where there is a sudden change of temperature, and generally of humidity as well, irregularities of flow develop, and from these irregularities cyclones and anticyclones originate. For a more complete description of this process, the student is referred to the Appendix, Chap. LI, and for a still more detailed discussion, to the selected references at the end of the chapter.

Cyclones are better developed during the winter than in summer. They originate most frequently in the higher latitudes and travel in an easterly direction across the country along the general paths shown in Fig. 112 at varying rates of speed, greater in winter than in summer, bringing our weather. Though relatively large, they are only small surface eddies in the general

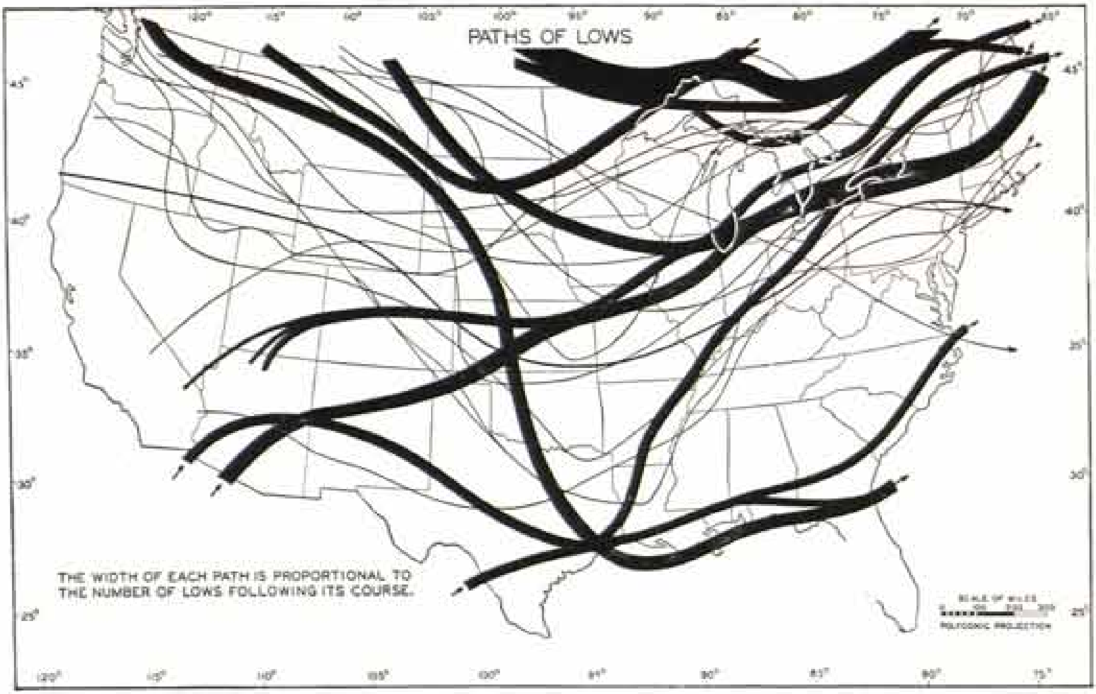

FIG. 112. Paths of low-pressure areas in the United States. (After the U. S. Weather Bureau.)

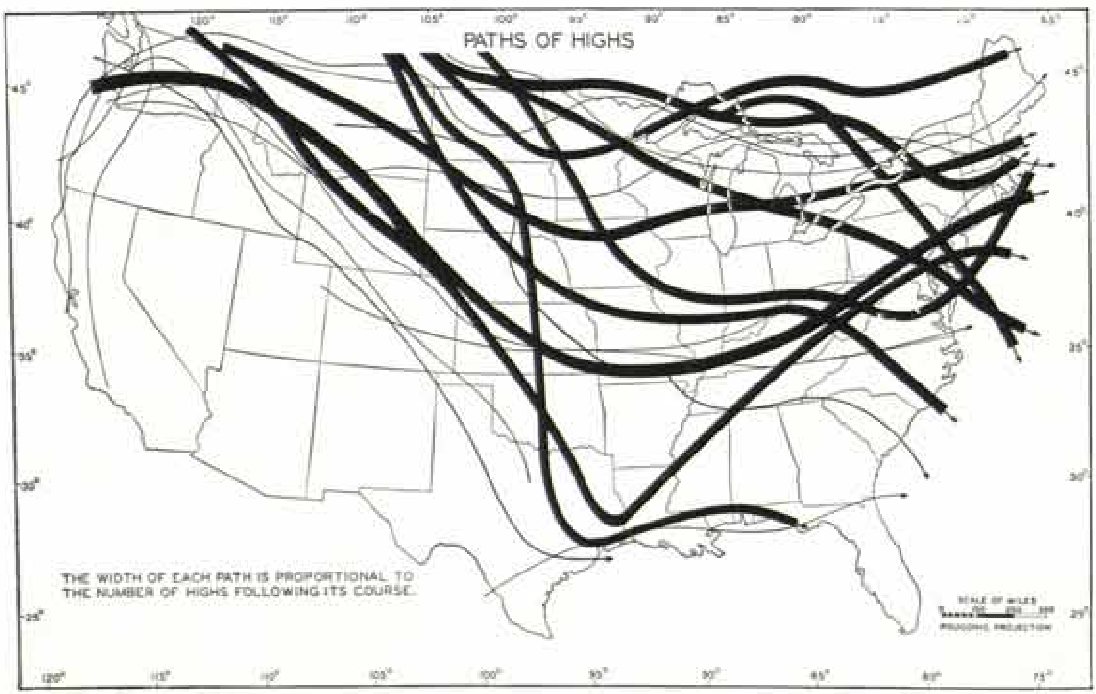

FIG. 113. Paths of high-pressure areas in the United States. (After the U. S. Weather Bureau.)

movement of the air: part of the general circulation, moving eastward in the general easterly drift of the westerlies. Some travel only a short distance and disappear; others may cross the Atlantic Ocean and reach western Europe; but, irrespective of size, distance of travel, or intensity, they are only secondary air movements. Like cyclones, anticyclones or high-pressure areas also travel in an easterly direction, as shown in Fig. 113, low- and high-pressure areas following one another in more or less orderly succession, particularly in the Southern Hemisphere, where large land masses do not interfere, though the regularity of this succession is subject to greater interruption in the Northern Hemisphere.

Thunderstorms. Thunderstorms are local storms of convectional origin with definite margins and at most only a few miles in diameter. They normally occur over land at times of high humidity during the summer months; they are rare but not unknown during the winter months. They are most numerous in the southern half of cyclonic disturbances, where conditions are most favorable for development of the convection currents which give rise to the heavy precipitation characteristic of such storms. "Dry thunderstorms," with little or no rainfall, are not uncommon in our western mountains, where they are responsible for starting many forest fires. The cooler weather which often follows thunderstorms gives rise to newspaper stories to the effect that the storms bring the cooler weather, whereas the correct statement should be that "the cooler weather brings the storm," the change of weather resulting from the importation of a mass of colder air.

Thunderstorm weather is likewise tornado weather, for when the air is hot and humid conditions are favorable for the development of these violent local disturbances in the lower atmosphere. Like thunderstorms, also, tornadoes are more frequent south than north of the major cyclonic tracks, for in the Lower Mississippi Valley where they occur with greatest frequency warm, moisture-laden air is drawn in from over the Gulf of Mexico.

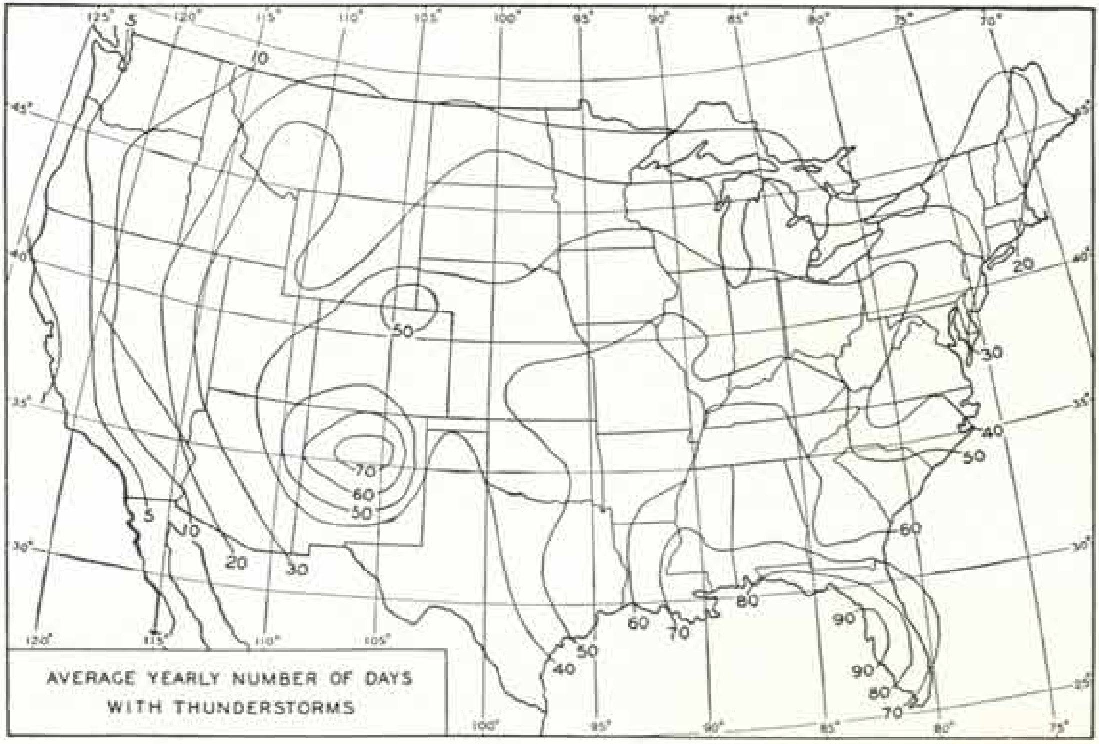

FIG. 114. Thunderstorms, being most numerous in the southern portions of cyclonic disturbances, are not of equally frequent occurrence in all parts of the United States. (After the U. S. Weather Bureau.)

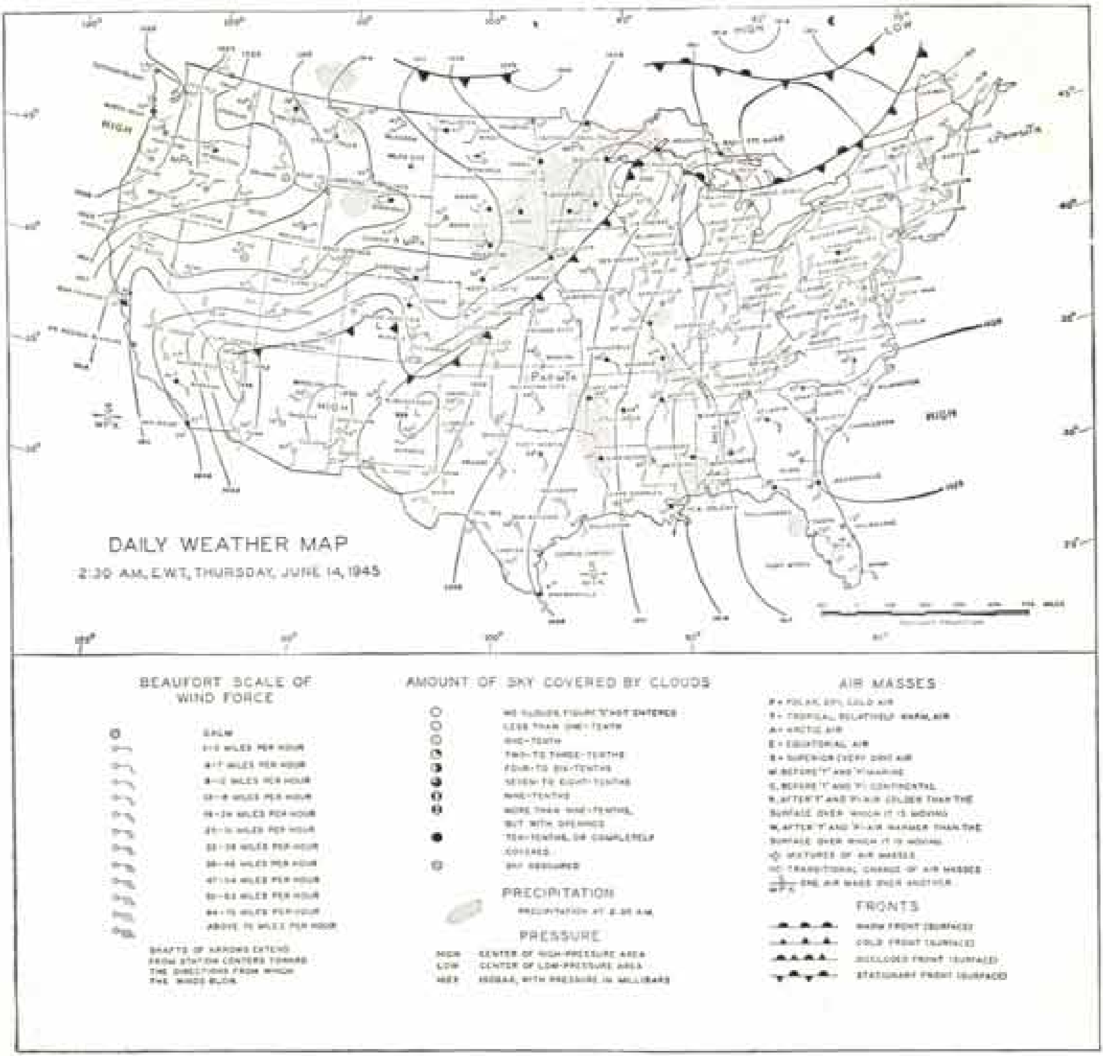

FIG. 115. A recent United States Weather Map, showing the location of the pressure areas and their relationship to the "fronts." (After the U. S. Weather Bureau.)

Weather Prediction. Forecasting the weather has obvious practical value, for it permits prediction of the probability of low temperatures and frost, the furnishing of advance information as to the time of arrival and the intensity of storms, and other uses of similar character. This is of value in both times of peace and war. Such predictions become a possibility because our weather is brought by cyclones and anticyclones, which travel in an easterly direction, along more or less definite paths, at approximately known rates of speed. This enables estimation of the probable time of their arrival and the weather they will bring. Weather predictions for short periods of time in advance are, therefore, based on a study of the pressure areas and related data for a given date, and the expectation that normal developments will occur during the succeeding 24-hour period. Taking these facts into consideration, it is possible to forecast the weather for one day in advance with a fair degree of accuracy. A rough prediction of similar character is possible for anyone who can read a weather map and, with practice and experience, such forecasts are often of value. A set of weather maps showing weather conditions for a period of sev-

eral days in length will be found in the Appendix, Fig. 456.

Until rather recently, all forecasts were based upon estimates of probable paths and rates of travel of the cyclones and anticyclones, and their individual characteristics. Today, however, this empirical method of prediction has been superseded by one based in part on studies of air masses, which has found favor with acceptance of the newer theories as to the origin of cyclones and anticyclones along the polar front. Such predictions are based on much more detailed and accurate observations of the upper air, as well as surface conditions. For a somewhat more complete consideration of this basis for predictions, the student is referred to the Appendix, Chap. LI. An even more extended discussion will be found in some of the selected references at the end of the same chapter.

Weather Proverbs and Weather Prediction. Most weather proverbs, representing as they do experience translated into words, have a basis in fact. This is apparent in the proverbs: "Every wind has its weather"; and "When clouds appear, wise men put on their cloaks." Similarly, sailors and others whose activities are affected by weather conditions may, and often do, make predictions of surprising accuracy for a few hours in advance, based on the appearance of the sky, wind direction and strength, and the "feel" of the air. Most persons, for example, know from experience that, when the wind shifts into the west and is of considerable strength, colder weather follows.

Long-range Weather Prediction. There is probably some correlation between ocean temperatures, movements of the ocean water, sun-spots, and the weather. Exactly what this relation is, however, and how it affects our weather is as yet uncertain. Therefore either seasonal or annual forecasts of temperatures and precipitation based on such data have no very substantial foundation and are frequently in error. If accurate, long-range weather prediction ever becomes possible, it will be of great value, for it will enable more intelligent planning for the future than is possible at present. This will be particularly true in agriculture, for it will make feasible intelligent regulation of crop production, tried with such disappointing results in recent years. Long-range predictions by amateurs, or those in almanacs, are generally based on the law of averages and are entirely undependable in exceptional years. Such being the case, they find acceptance only among the credulous.

"Our Changing Weather and Climate." Weather records for the past 100 or more years indicate that neither the weather nor the climate is changing, and certainly no observable permanent change has occurred within the range of the personal experience of any individual. Beliefs to the contrary are based on the fact that human memory is fallible, and upon differences in the impression made by such a phenomenon as a 3-foot snowdrift on a small boy and a mature individual. To the small boy, the drift appears very deep; to the man, of relatively slight depth. But when the man recalls his childhood days, he remembers the 3 feet of snow as it impressed him when he was young. Therefore he concludes, on the basis of this remembrance, that the snowfall of the present is lighter than that of the past. It is possible, of course, that there is some evidence to the effect that our climate may be changing slowly but, if so, the change is much too slow to attract the attention of the average individual. At present, the preponderance of informed opinion indicates no perceptible, permanent change in either our weather or our climate.

Weather Elements and Their Combinations. The elements which make up the weather vary within wide limits, both independently and in almost infinite combination, so that temperature, moisture, and wind conditions are never duplicated exactly in any two successive days in our latitudes. For this reason, as stated earlier, "as fickle as the weather" has come to mean the maximum of undependability. In practice, however, the weather of a given place on any date is something more than a random sampling of all the possible combinations of the weather elements. Thus, during the summer months of intermediate latitudes extremely low temperatures are impossible at or near sea level, and during the winter months of these same areas, extremely high temperatures are unknown, so that the possible combinations of weather conditions are limited in number, and still further by the fact combinations occurring on successive days are not independent of one another. Thus we have a spell of warm weather followed by a colder spell, with the weather much alike in either for a period of several days. As a result of these limitations,

the term "summer weather" has a definite meaning, and when we speak of "winter weather" a definite concept of weather conditions is conveyed. This is even more true when we describe seasonal characteristics in the tropics, where monotony of weather conditions is commonly much more marked than in intermediate latitudes, where cyclonic disturbances as they travel eastward introduce the unexpected with expected regularity.

Not only is there a certain degree of sameness in the weather from day to day in a given locality, but there is likewise similarity in the change of conditions from season to season, and in the weather of a given season from year to year in the same place. Thus one area may have long, cold winters and short, hot summers, with light precipitation normally falling in greater part during the summer months, with variation in these respects only within the relatively narrow limits imposed by the general character of the climatic conditions. By contrast, a second may have high temperatures throughout the year, and abundant, well-distributed precipitation. Variation from day to day, or over longer periods of time, will again be within limitations imposed by the general climatic conditions of the specific area.

The Basis for Climatic Classification. Recognition of these general similarities of weather conditions in definite areas, in what on first consideration appears to be the endless confusion of the changing weather, makes generalizations on climate possible. It likewise permits classification of the climates of the world into a relatively small number of types, within each of which a certain allowable variation occurs from day to day, week to week, month to month, and year to year.

This classification is based first on recognition of climatic types in which precipitation is ample and those in which it is deficient in amount. Then the climatic types of ample precipitation are subdivided on the basis of major temperature differences; again on that of precipitation distribution; and, once more, on the basis of minor temperature variations. Similarly, the dry types of climate are subdivided first on the basis of the amount of precipitation, and, again, on that of temperature conditions. A more detailed discussion of climatic classification and of types recognized, accompanied by a map showing their location, will be found in the Appendix, Chap. L. Still further amplification of this discussion is available in the selected references listed at the end of the chapter.

QUESTIONS AND EXERCISES

1. What is the depth of the atmosphere? What subdivisions of the atmosphere are recognized? What are some of the characteristics of each of these subdivisions? Which one of them promises to play a more important part in our life in the future than it has in the past? Why?
2. Why is it correct to say that the winds bring the weather? What weather do they bring in the doldrum belt? In trade-wind areas?
3. What instrument is used for measuring air pressure? Upon what principle does it depend? How is it read? How may it be used to assist in making weather predictions for short periods of time in advance?
4. To what are the characteristic spells of weather of intermediate latitudes related? How and why? Why is it fair to refer to our weather as "intemperate"? In what respects, if any, is this variability an advantage?
5. How and where do cyclones and anticyclones originate?
6. In what direction do cyclones travel? Why? During what season of the year are they best developed? What relationship do they bear to the general air circulation?
7. What is a thunderstorm? Why are thunderstorms of most common occurrence during the summer months? What is a "dry thunderstorm"? Of what importance are such storms? What is the relationship of thunderstorms to cyclones? In what parts of the United States are thunderstorms most frequent? Do thunderstorms actually bring cooler weather? Why is it a common belief that they do?
8. What general weather conditions are favorable for the occurence of tornadoes? What relationship do these storms bear to cyclones?
9. What is the basis for empirical weather prediction? What is the basis used by the United States Weather Bureau at present?
10. What is a weather proverb? State several. Upon what are such proverbs based?
11. What is the present possibility of accurate, long-range weather predictions? How reliable are long-range weather predictions in almanacs? Upon what are they based?

12. Is our weather or climate changing? Why is it a common belief that weather and climate are changing?
13. In what respects is the weather something more than a random sampling of all the possible combinations of the weather elements?
14. On what basis are climates classified?

SELECTED REFERENCES

Blair, T. A., *Climatology*, Prentice-Hall, Inc., New York, 1942. Part I.

This section of the text, 128 pages in all, is devoted to a rather comprehensive treatment of general climatology. In it are considered temperature, wind, and moisture, as climatic elements; climatic contrasts; climatic variability; climatic influence; and climatic classification.

Bliss, G. A., *Weather Forecasting*, U. S. Department of Agriculture, Bulletin No. 42, 6th ed., Washington, 1939.

This is a popular discussion of weather forecasting, accompanied by maps and diagrams. Forecasting from local conditions and the basis and reliability of weather proverbs are also considered.

Trewartha, G. T., *An Introduction to Weather and Climate*, McGraw-Hill Book Company, Inc., New York, 1943, Chaps. IV, V, VI, VII, VIII, IX, X.

These chapters, in the order listed, cover the following subjects: air masses and fronts; storms and their associated weather types; tropical rainy climates; dry climates; humid mesothermal climates; humid microthermal climates; polar and highland climates. Accompanying bibliographies will provide sources of even more detailed discussions of these topics.

Chapter Sixteen

SOILS

Soil. Soil consists of disintegrated and chemically altered rock material, mixed with varying percentages of organic matter. Ground up rock is not soil, for fragmentation alone produces only finely divided rock from which soil may be formed if additional alteration by weathering of the small rock particles and change produced by the incorporation of organic material occur.

The organic material in the soil is composed of both living organisms and the residues of living matter. This latter homogeneous, dark-colored mixture of compounds, representing a stage in the decomposition of the organic matter, but without definite chemical composition, is known as "humus." In ordinary mineral soils, the organic fraction is 20 per cent or less; when the amount increases beyond this percentage, sometimes to as much as 95 per cent in peat, the soil is classed as organic in type.

Change in the soil, physical, chemical, and biological, is continuous. Therefore the soil is a complex substance in which conditions are never static. Measured in terms of the extent of these changes, soils are described as young, mature, and old. Since the operation of soil-forming agencies and their results are not uniform, soils differ from place to place. Therefore they vary in both potentialities and use. At an earlier period of history, when self-sufficiency was the rule, this was of great importance, for local soil characteristics affected diet; today, with extensive development of trade, this is true to only a limited extent.

Agricultural Desirability of Soils. The agricultural desirability of a soil depends on its depth, texture, structure, and composition. For a correct evaluation of the potentialities of any soil under use, it is necessary to know all four of these characteristics and their effects.

Soil Depth. In a state of nature, soil is forming continuously at or near the surface by alteration of the underlying parent material. At the same time, soil is being removed at the surface by the agencies of erosion: wind and running water. If soil formation is in excess of soil removal, the soil increases in thickness; if the two processes balance one another, the soil remains unchanged in depth. If removal is excessively rapid, however, not only the soil but much or all of the unconsolidated parent rock material as well may be carried away, in extreme cases leaving the solid rock to form the actual surface.

Normal erosion, or removal of material from the surface at a rate which permits maintenance of constant and sufficient soil depth, may not be detrimental and is often beneficial, for it removes the surface layer gradually, thus exposing new material upon which the soil-forming agencies may work. This is particularly true in the humid tropics, where chemical weathering is very active and extends to considerable depths so that the surface layer of soil soon becomes "old" and unproductive. This is one reason why moderate slopes in such areas, from which soil is removed gradually but continuously, may pass into profitable agricultural use, whereas adjacent flat land remains uncleared. Accelerated erosion, however, resulting from misuse of the land, is always objectionable, even in the tropics.

The rate of soil removal varies with several factors, one of the most important being degree of slope, which affects rapidity of runoff, thereby determining the ability of the running water to transport material in suspension. From this it follows that soils tend to be shallower on slopes and deeper on flat land. Though this may make the soils on moderate slopes in the tropics more desirable, the reverse is true in intermediate lati-

tudes. This is because chemical weathering of the mineral and oxidation of the organic material of the soil are less rapid and seldom continuous in the higher latitudes. Therefore, when the topsoil, in which change has been considerable but not excessive, has been removed, that which remains is commonly less productive and hence less desirable for agricultural use. It should be remembered, of course, that factors such as climate, vegetation cover, and others, as well as steepness of slope, affect both rapidity of runoff and the deterimental rate, and that they are, therefore, important in determining the exact depth and desirability of the soil on any given slope.

Accelerated Erosion. The problem of accelerated erosion is not new. It is almost as old as agriculture, as has been noted in an earlier chapter. In the American colonies, culturally induced erosion began in Virginia with tillage of slopes, for early agriculture of the exploitive type, with tobacco the major cash crop, tempted disastrous practices. By 1769, the soils of Mt. Vernon were washing perceptibly and George Washington was considering experimenting with contour plowing. Shortly after the American Revolution, the remark attributed to Patrick Henry to the effect that "since the achievement of our independence, he is the greatest patriot who stops the most gullies" indicates how widespread the problem had become. In 1817, Thomas Jefferson commented that "fields are no sooner cleared than washed." Though attempts at control were beginning by the end of the eighteenth century, and though most of the practices in use today for its prevention were either developed or known during the first half of the nineteenth, gullying and attendant "soil exhaustion" soon became so common that they were regarded as normal by most Virginians of those periods, as they have been until rather recently throughout most of the South. Individual farmers, it is true, have been combating soil erosion for nearly 150 years, but general appreciation of the seriousness of the problem has been lacking, and all too often erosion and destruction of fields under cultivation have been regarded as inevitable under any economically profitable cropping system.

Conditions Favoring Accelerated Erosion. Removal of the cover of native vegetation with agricultural use of the land, or its destruction by grazing, is productive of conditions which lead to accelerated erosion. Plowing pulverizes the virgin soil, destroying its natural permeability and obstructing or closing natural openings made by plant roots and the tunneling of earthworms and burrowing animals. Such of these openings as are not destroyed by cultivation are filled with fine material, deposited from surface runoff. Continued cultivation also decreases the humus content, the spongelike character of which adds to the water-absorptive power of the soil. Overgrazing depletes or even destroys the native vegetation, the roots of which hold soil in place. Then the soil, trampled by livestock and baked by exposure to the sun, becomes hard and compact, an easy prey to running water, especially on the steeper slopes. Thus misuse of the land tends to increase the fraction of the rainfall which runs off, thereby promoting accelerated erosion.

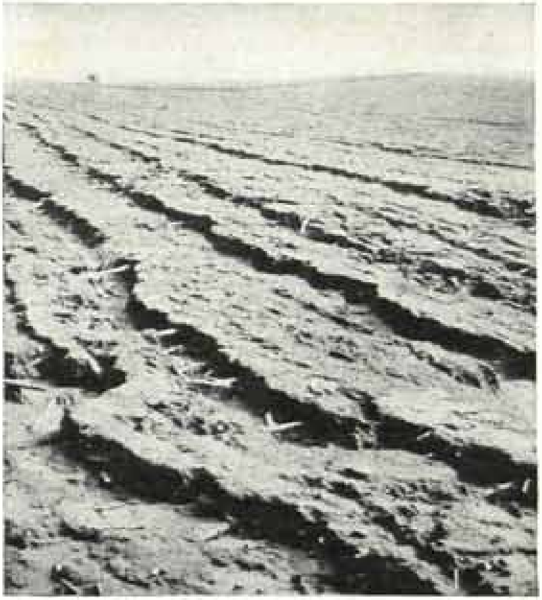

FIG. 116. The result of several heavy rains falling on a moderate slope near Bethany, northwestern Missouri. Broken from sod 3 years earlier, this field has been in corn each year since, which, in connection with tillage without attention to slope, has produced serious slope wash. (Courtesy of the U. S. Soil Conservation Service.)

The percentage of the rainfall which runs off, an important factor in determining the amount of erosion, is in part related to soil type. With very coarse sands, absorption of water is great, runoff is slight, and soil erosion is normally not serious. With finer grained soils, such as silts and clays, structure rather than texture becomes impor-

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tant. With a granular structure, in which the grains function as *aggregates*, runoff and erosion may be slight, but with a single grain structure it is often serious. The organic portion of the soil not only has a greater water-absorptive capacity than the mineral, but it also increases soil porosity and permeability by promoting a granular structure. Almost universally, therefore, soils of low organic content erode rapidly.

Both length and steepness of slope likewise affect total runoff and the amount of erosion, but variably with intensity of rainfall. Thus even on long, gentle slopes with permeable soils, the percentage of runoff with heavy precipitation may be high, though the reverse is true with rains of lower intensity. Always, however, erosion is more serious on the steeper slopes, because of the greater *rapidity* of runoff. Therefore soils tend to be thin on such slopes.

Climate and Erosion. Climate affects both the type and rate of accelerated erosion. Sheet wash and gullying are the predominant types in well-watered areas; wind erosion is effective chiefly in arid and semiarid regions. Within any given humid area, the rate of soil removal is directly related to rainfall intensity, duration, and distribution; within a dry area, to the length of the rainless periods and the distribution and intensity of the precipitation. Temperature, though of lesser, is of considerable importance, both as an agent of weathering supplying loose material subject to erosion, and in producing mass movement of soil *down* the slope. Wind, though potentially an agent of erosion everywhere, is important only in the drier areas and in those parts of humid regions where the vegetation cover has been destroyed. By promoting rapid evaporation, winds also tend to produce conditions favorable for their action as agents of erosion in all areas.

Relation of Erosion and Thin Soils to Crop Yields. Though frequently attributed to depletion of soil fertility, so-called "soil exhaustion" often results from soil erosion, for as the topsoil disappears plowing turns up some of the subsoil, and, finally, nothing but subsoil. This is often inferior clay, sand, or even loose rock, the cultivation of which is often unprofitable and always disappointing in results, for even when fertilized returns are low.

Experience indicates that with intelligent farm practices, yields tend to remain constant or even increase on the better land not subject to excessive erosion. On the poorer, badly eroded fields, where the soil has all been removed and crops are grown on the subsoil, however, maintenance of yields is difficult and in many cases impossible, irrespective of farm practices. Field studies show that, under this latter condition, yields may average "77 per cent below those of corresponding areas still retaining a good cover of topsoil." The more important of the causes producing this startling decrease are: deficiency of nitrogen content, poor soil structure, and the limited subsoil supply of available minerals used by plants. Wherever erosion becomes so serious that production is abandoned on large, formerly cultivated acreages, thereby restricting cultivation to the less severely damaged areas, it is normally true that average crop yields for the region rise sharply.

Extent of Soil Erosion in the United States. No exact data as to the extent of erosion are available, and it would probably be impracticable to assemble such data for any given date, since erosion is a continuing process. According to the United States Soil Conservation Service, at least 50,000,000 acres of land, approximately 5 per cent of all land in farms, or 12 per cent of the cropped acreage in the United States, have been ruined and are incapable of further use. Most of this land has already been abandoned. In addition, another 50,000,000 acres will soon share the same fate and should be withdrawn from cultivation promptly. Twice as much more, or over 100,000,000 acres, has lost from one to three-quarters, or even more, of the topsoil. It is estimated that, in all, more than half the land area of the United States has been affected adversely in some degree by erosion.

Further, most of the serious erosion is concentrated in areas long in agricultural use, an indication of what the future holds in store for others. In certain areas, as much as 25 per cent of the land has passed out of use permanently, destroying the basis for local support of necessary community services, thus creating a state and national liability. An example of this condition, cited by H. H. Bennett, is afforded by Stewart County, in northeastern Georgia, where gullies are often "huge, yawning chasms 100 feet or more in depth." This county was ruined by erosion 30 years ago. Similarly, in the Black Belt of Mississippi and Alabama, soil removal is so complete, in what was formerly one of the most

productive portions of the southeastern states, that it is now almost impossible to find a trace of the original dark-colored prairie soil, and even the subsoil has been removed over considerable areas.

Unfortunately, these conditions are not confined to a few localities nor to areas which have been in agricultural use for many years. Erosion is serious, even in recently settled sections in Oklahoma; and in the northwest, in Washington, Oregon, and Idaho. Further, not only running water but wind as well takes a heavy toll of soil from the Great Plains, in the southern portion of which, known as the "Dust Bowl," approximately 75 per cent of the total area has been affected adversely, and nearly 50 per cent seriously by wind erosion alone.

Soil Texture. Soil texture is determined by the size of the constituent mineral grains. If they are rather large, the soil is a gravel; if somewhat small, 2 to 0.05 mm. in diameter, a sand; if still smaller, 0.05 to 0.002 mm. in diameter, or barely visible to the naked eye, a silt; and, if very fine, less than 0.002 mm. in diameter, a clay. This fine clay, plus much of the organic residue of the soil, make up what is technically known as the "colloidal" portion. The particles of this part of the soil are so fine, averaging 0.0005 mm. or 0.000002 of an inch in diameter, that under appropriate treatment they remain suspended in water. They are known as "colloids" from the Greek word for glue, "kolla," because of their adhesive characteristics. The coarse and medium-sized soil grains are largely inert, but the colloidal clay and organic material serve as a source of plant nutrients and determine how much water can be held by the soil. Therefore their presence is highly important for successful crop production and profitable agriculture.

Though there is no necessary difference between sands, silts, and clays, other than grain size, they normally vary in chemical composition as well. Further, few if any soils are composed exclusively of grains of sufficient uniformity in size to be classified accurately as sand, silt, or clay, most soils being mixtures composed of various percentages of particles of different sizes. Such mixtures are known as "loams." If a loam contains much sand, it is described as a sandy loam; if still more sand, as a light sandy loam; only if almost pure sand, as a sand. Similarly, soils may be clay loams, silt loams, or other mixtures of different combinations of the various grain sizes.

Soils are sometimes said to be "cold" or "warm," dependent on texture. Sandy soils, which dry out readily and warm rapidly, are warm soils; moisture-retentive soils such as clay, which remain cold until late in the spring because of their high water content, are cold soils. The terms "heavy" and "light" are also used in describing soil texture, clay soils being heavy; sandy soils, light. These terms, used in connection with soils, have no relation to weight but only to textural characteristics.

The desirability and uses of soils vary markedly with textural characteristics. Light sandy soils, with low water-holding capacity and small colloidal content, are of relatively low value for general agricultural use, but they lend themselves to use for market gardening because they dry out and warm rapidly in the spring, hence allow early planting and profitable marketing of crops. On the other hand, the heavier soils of higher colloidal content, such as silt loams of medium grain size, which retain water more effectively, are valuable for production of the major field crops. Very heavy soils such as heavy clays are poorly aerated and of lower agricultural desirability.

Soil Structure. The structure of soils is determined by the arrangement of the soil grains. In some cases, each grain functions as an independent unit; in others, the grains function as aggregates, several clinging together. If of single grain structure, a soil is hard and impervious, shedding rather than absorbing water. When the grains function as aggregates, so that a granular or "crumb" structure results, the soil is loose and friable, and its physical condition is such that productivity is greater. Inasmuch as the size, shape, and stability of such aggregates influence soil productivity, maintenance of favorable structure of soils under cultivation is highly desirable. Many agricultural practices, such as the addition of organic matter, serve in part to promote aggregation of the soil particles and thus improve the "tilth," or the physical condition of the soil.

The physical condition, or the structure of the soil, determines its liquid and gaseous content, both important in affecting crop yields. The liquid portion, or the soil solution, a major source of raw materials from which plant foods are made, consists of water containing mineral matter, car-

bon dioxide, and oxygen, in solution. If these are in proper balance, conditions for plant growth are favorable. The gaseous constituents are important because normal upland plants or crops will not grow in waterlogged soils. Satisfactory soil structure is, therefore, fundamental for profitable agriculture.

Soil Composition. Plants use a considerable number of minerals which they absorb, largely dissolved in water, through their roots. A few years ago, ten elements were considered essential for plant growth: carbon, hydrogen, and oxygen from the air and water; phosphorus, sulphur, nitrogen, potassium, calcium, magnesium and iron from the soil. Today, we know that manganese, copper, zinc, boron, and possibly others, are also necessary in minute quantities.

All soils contains most of these elements in amounts sufficient to meet plant requirements. For example, green plants need iron to make their green coloring matter, or chlorophyll, without which they cannot produce sugar and starch. Therefore, if a normally green plant were grown in a soil lacking iron, it would be white in color, would be unable to make sugar and starch, and consequently it would die. Fortunately, all soils contain sufficient iron so that it is never necessary to add it to permit plant growth. Despite this fact, it is today believed that man may suffer from anemic conditions as a result of consumption of plant foods grown on iron-deficient soils. Soils are, however, frequently low in potash, phosphate, and lime, compounds containing elements necessary for the effective growth of crops. Therefore it is often the practice to remedy this deficiency by the application of fertilizers containing these substances. The first two, potash and phosphate, are added either to promote plant growth or to increase crop yields; the third, lime, to "sweeten the soil," or to correct soil acidity, for certain crops such as clover and alfalfa cannot be grown in lime-deficient soils. In addition, the lime serves other purposes such as improving the physical condition of the soil. Occasionally it may be necessary to add still other substances in small amounts for the successful production of certain crops. Deficiencies in soil composition may be remedied either by the use of commercial fertilizers which contain the desired plant nutrients, or by the application of animal and other farm wastes.

The "Soil Miner." The American farmer who grows only a single crop such as wheat is frequently characterized as a "soil miner" because he first "mines" and later sells the soil minerals when he markets his crop. Thus some of these are removed from the farm each year, so that the amount remaining in the soil for use by the crops of the following years becomes less year by year. This is reflected in decreased yields. When virgin soil is brought into production, therefore, the initial high yields are followed by smaller and smaller returns per acre under cultivation, as the original store of mineral plant nutrients is depleted gradually. Yields will not, however, decrease to zero, no matter how long a field is cropped, even though no fertilizer is applied, for new soluble minerals essential for plant growth are being released continually by alteration of the parent matterial from which the soil is formed. When a balance between removal and formation of a supply of available minerals is finally attained, crop yields as determined by soil composition remain constant. But, when this occurs, yields may be, and commonly are, so low that agricultural use of the land is no longer profitable.

Crop rotation, that is, growing a given crop only every other or every third year on a field, with other crops claiming the land in the intervening period, is a desirable practice, for this not only has a tendency to maintain constancy of yields, but it also enables the farmer to work more effectively by spreading his work over a larger fraction of the year. Sacrifice of the future for a greater immediate return, the common practice in much American agriculture, is not the rule in all parts of the world, for in eastern Asia the Chinese and Japanese have, by heavy manuring, largely with human wastes, used land in production for many centuries without impairing yields.

Soils Derived from Residual Material. Many soils are derived from residual material, or the residue resulting from disintegration and decomposition of the country rock in place. Where this is true, there is a gradual transition from solid rock, through partially disintegrated and altered rock, the parent material, into the surface soil. Under such conditions, soil characteristics are affected to a considerable extent by the kind of rock which underlies the surface. Therefore change in the underlying rock is reflected in soil type, agricultural practice, and rural prosperity. If the country rock is sandstone, the soils will be sands; if a shale, they will generally be stiff, yel-

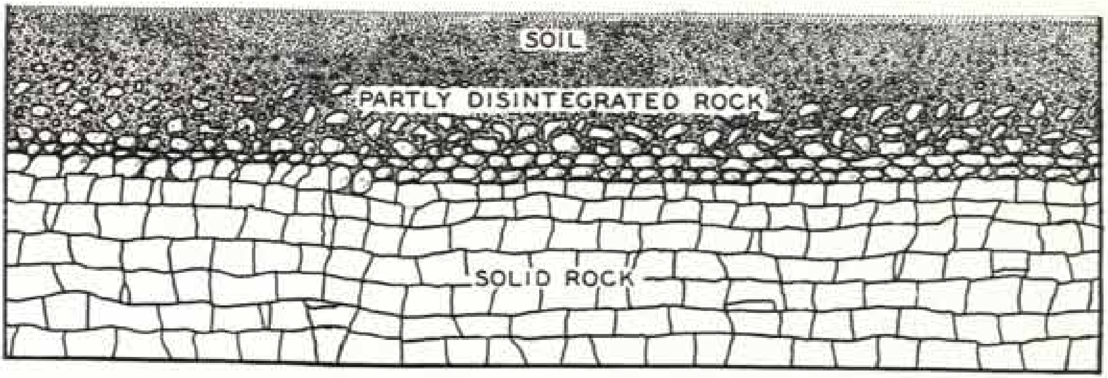

FIG. 117. Transition from solid rock to soil in an area where the soil is derived from residual material. Compare with Fig. 118.

low clays of low productivity, which wash badly under cultivation; if a limestone, they will commonly be silt or clay loams of high fertility. Still other types of soil, some desirable, others poor, will result if the residue is derived from other kinds of rock.

All soils derived from residual material are subject to certain limitations. If the rock is lacking in certain materials essential for plant growth, these will likewise be absent in the soil, which, derived as it is insofar as its mineral constituents are concerned exclusively from the underlying rock, cannot contain minerals lacking in the parent rock material. Further, the soil is often deficient in minerals present in the underlying rock, particularly those readily soluble in water. Thus soils derived from limestones may be deficient in lime because, in the process of change from rock to soil, the limestone dissolves and is carried away in solution. Formed under desert conditions, soils derived from residual material average higher in mineral plant nutrients than do those in humid regions, since leaching is less active or absent in dry areas. However, as has been noted earlier, when such soils are used under irrigation, the normal processes of better watered areas become operative, and the soils decrease in desirability.

Soils Derived from Transported Material. Four agencies are important in transporting material from which soils are derived: (1) running water in rivers; (2) glacial ice; (3) waves and currents in lakes and other bodies of water; and (4) wind. All of these are competent to move material of various grain sizes from the point of its origin and deposit it in other locations, where it forms the parent material from which soils are derived.

The material transported and deposited by streams is known as "alluvium," which may be

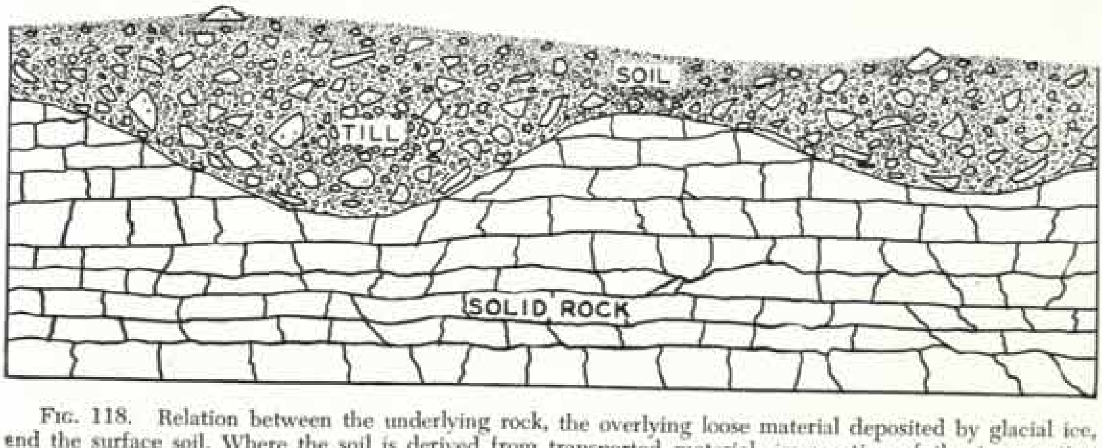

FIG. 118. Relation between the underlying rock, the overlying loose material deposited by glacial ice, and the surface soil. Where the soil is derived from transported material, irrespective of the transporting agency, the gradual transition from solid rock to soil is absent. Compare with Fig. 117.

coarse gravel, sand, silt, or clay, dependent on stream velocity. Deposition occurs as a veneer on the flat land bordering rivers, particularly in nonglaciated areas where flooding of such flat land is most common. Thus inhabited, agricultural Egypt is the "gift of the Nile."

During rising river stages, with accompanying increase in stream velocity, there is relatively little deposition, but with subsidence and decrease in rapidity of flow, much deposit occurs. The first material dropped is the coarser gravel and sand, mostly near the stream banks, or wherever the flood waters are shallow. Farther from the river, the deposit is generally silt; still farther away, particularly near the valley walls, it is fine clay. Though alluvium varies greatly in texture, the bulk of the deposit of our larger rivers, such as the Mississippi and Nile in their lower courses, is of the finer material.

Soils derived from this finer alluvium are commonly of high fertility since the material is largely topsoil, supplied by slope wash and assembled from such a variety of sources that all minerals essential for plant growth are present. Topographic conditions are likewise favorable, so that soil removal is slight and accumulation is continuous from year to year. Further, the water table is seldom far below the surface so that drought risk is not excessive. Except for danger from inundation, and excessive leaching in the older alluvial deposits, the opportunities for agriculture on soils derived from alluvium are attractive. Therefore, when protected from overflow, the land generally passes into profitable agricultural use where climate and market conditions are favorable. The popular concept of a valley as a fertile area is based upon the fact that the soils are derived from alluvium.

Till, or material deposited directly by glacial ice, varies in texture, ranging from huge boulders to the finest of clays, deposited as a heterogeneous mass of fine and coarse material, ranging in thickness from a few inches to a hundred feet or more. Not only does the deposit vary in depth and textural characteristics, but topographically as well. In some places, the land is flat or gently rolling; in others, it is hummocky or hilly and slopes are steep. Further, such deposits are often stony and likewise frequently "patchy" in distribution. In part, this is because deposits of sand and gravel, laid down by water running away from the front of the ice sheet, are interspersed with the unsorted deposits of till. These deposits like those of till, vary from flat to hilly in character, but they differ from those of till in that the materials are sorted sand and gravel.

Till commonly weathers into soils of fair to high desirability, some of the best agricultural areas in the United States having soils derived from material deposited with the melting of the ice sheet during and at the close of the last glaciation. Such desirability derives from the fact that glaciation crushed but did not otherwise alter the rock material. Therefore, unless excessive leaching occurred subsequent to deposition, the parent material, supplied by many and often diverse areas, still contains the minerals needed by plants, if they were in the rocks prior to crushing by ice action.

Lacustrine deposits originate on lake bottoms. They are composed of sediment dropped by inlet streams where their velocity is checked on reaching the lake; and of material torn from the shores by wave and ice action and distributed over the lake bottom by currents and other movements of the lake waters. In such deposits, the coarser particles, sand and gravel, are dropped near the shore and the clay farther out in the deeper, less disturbed water. Such materials, being deposited under water, are subject to leaching and therefore to loss of soluble minerals. On exposure of the lake bottom from any one of a number of causes producing lowering of ground-water level, soils of fair productivity originate from the finer material of such deposits. Along the old shore lines, however, where they are sand and gravel, soils are poor. An outstanding example of an area in the United States with soils derived from lacustrine material is the Red River Valley of Minnesota and the Dakotas, the former bottom of Lake Agassiz, which covered this area toward the close of the last period of glaciation in North America.

Wind is able to transport only the finer soil-forming materials such as sand, silt, and clay. When sand is moved, it often drifts, much as does snow, to form dunes. Though frequently much higher, these have the same form as snowdrifts, with the steep face on the lee or sheltered side of the dune. Dunes, sometimes attaining a height of as much as 200 feet, are found wherever there is sand which dries out sufficiently so that it can be moved by wind, with such conditions occurring in deserts and along the shores of great rivers, lakes, and the ocean. These areas of drift-

Fig. 119. Active dunes advancing to the right, or north. Note the gentle slope and rippled surface of the dune on its windward side, its steep slope on the north or lee side. Looking west on the south side of the Arkansas River Valley, about 4 miles west of Syracuse, southwestern Kansas. (Courtesy of H. T. U. Smith.)

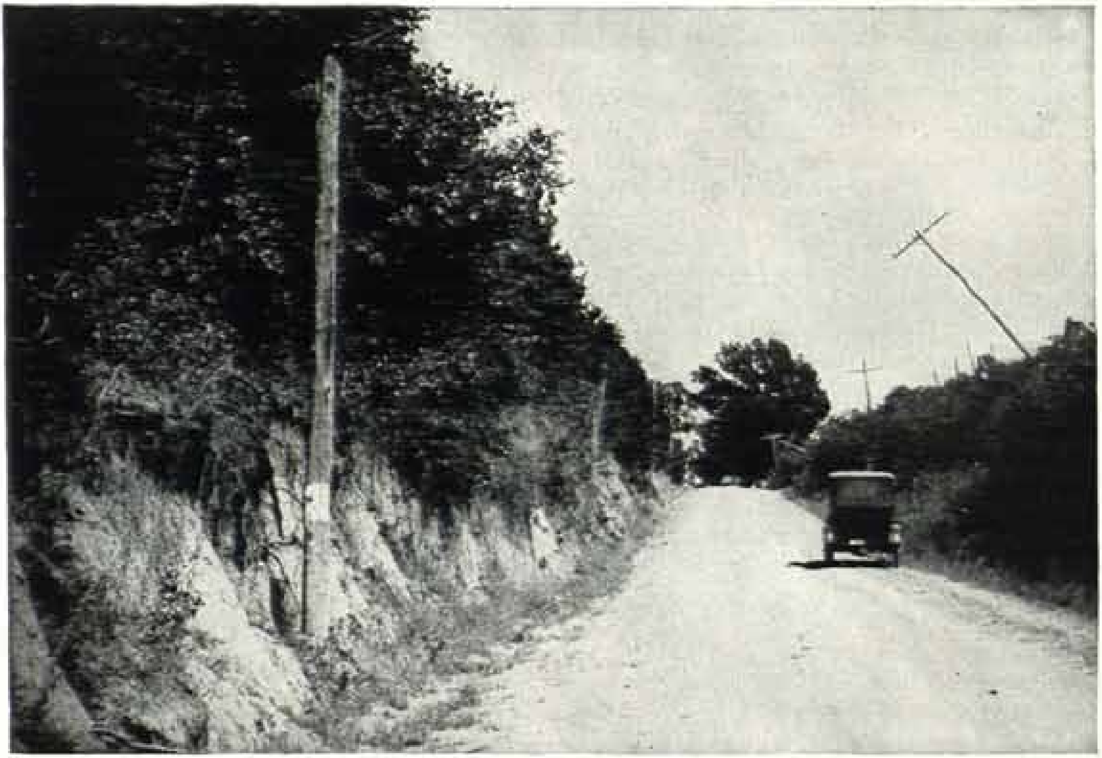

Fig. 120. A road cut in loess, Fulton County, southwestern Kentucky. Note the vertical sides of the cut.

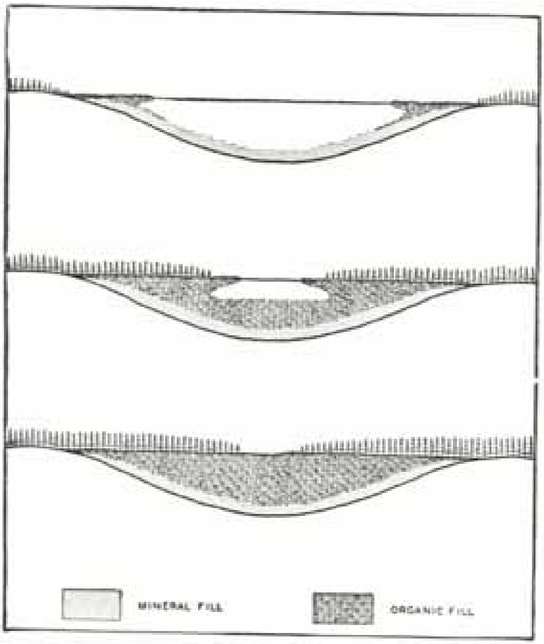

FIG. 121. Three stages in the formation of a peat bog in a shallow depression. In the uppermost of the three figures, the shallow, soft-bottomed lake is fringed by marsh; in the middle figure, encroaching vegetation has captured most of the lake and organic fill is extensive; in the bottom figure, the lake has disappeared completely and a peat bog marks its former site.

ing sand are of little of no agricultural value, and movement of the sand may cause considerable inconvenience or even loss in adjoining areas by blocking highways, covering fields, burying forests, and, occasionally, houses and small villages. Locally, as in the vicinity of Chicago, and along the shores of Lake Michigan, the dune areas with their clean sand afford recreational possibilities.

When the material transported by the wind is very fine, the deposit formed, known as "loess," weathers into highly productive soils, even under continued use, for new material is added yearly at the surface, at least in North China, where agriculture is centuries old. Generally, this deposit is mixed with others, or at most it forms only a thin surface layer, but in the Rhine, Danube, and Missouri-Mississippi valleys, the deposits are often many feet thick. In North China, they even reach thicknesses of 1500 to 2000 feet, according to Cobb. Loess is peculiar in that it stands, as does solid rock, in vertical faces along the sides of cuts, for which reason roads in loess areas tend to intrench themselves as the dust raised by passing vehicles blows away. In North China, this depression of the roadbed below the general level of the country is sometimes as much as 30 feet or more. The Chinese take advantage of the fact that loess does not slump, as does other unconsolidated soil-forming material, to excavate houses in the steep-sided loess bluffs which face depressions and border valleys of the Loess Highlands of northern China.

Soils Derived from Organic Materials. Soils of marshes, swamps, muskegs, moors, and fens, where conditions are favorable for rapid and extensive accumulation of organic material, are derived largely from such deposits. Such soils are known as "mucks" and "peats," various means of differentiation between the two being recognized. One of the more common is based on the percentage of organic material present. On this basis, a soil may be classed as peat if the organic material exceeds 70 per cent; if less, but more than 20 per cent, as muck; if below 20 per cent, as an ordinary mineral soil.

Organic material accumulates in sufficient amount to be important as a major soil-forming material only under certain favorable climatic and topographic conditions. In arid areas, vegetation is too sparse to make appreciable accumulation of plant remains possible; if rainfall is abundant and temperatures are continuously high, decay is so rapid that but little organic material is preserved. Only in well-watered areas with cold winters and summers of sufficient length to permit abundant plant growth does climate permit formation of muck and peat. Hence such soils are common only in the higher intermediate latitudes, particularly in the Northern Hemisphere, where land masses are extensive. Further, topographic conditions must be favorable, since preservation and accumulation of organic material in considerable quantity occur only where the surface is either wet or covered by water to a slight depth. Therefore muck and peat are found in shallow depressions and covering flat, poorly drained areas, or heath, where the soils are lime deficient. These conditions occur in the swamps of the coastal plain of southeastern United States, where soils such as those of the Everglades of southern Florida are mucks. They likewise occur in the glaciated areas of northeastern United States, where numerous shallow depressions and flat, poorly-drained

areas, in combination with low winter temperatures, afford conditions favorable for the accumulation of peat. In Minnesota, for example, one-seventh of the land surface is covered by peat to a depth of 3 feet or more. There, the larger and more important deposits occur on flat, poorly drained land such as the former bottom of glacial Lake Agassiz.

Since peat varies in origin, texture, and lime content, it differs in type and potential value from place to place. The common peats of the higher latitudes, of some value for fuel but of low desirability for agricultural use, originate largely from accumulation of the remains of sphagnum moss. Those of somewhat lower latitudes, formed from the remains of sedges, grasses, and similar herbaceous plants, are better adapted for use in crop production. The best of all for agricultural use are the structureless peats of sedge-grass bogs, the waters of which are hard or have a high lime content.

The only important uses of peat are: (1) for fuel; and (2) for agriculture. Sphagnum peat is used rather extensively as a fuel by the peasants of northwestern Europe, where human labor is cheap, working hours are long, and standards of living are low. In this country, with an almost limitless tonnage of good, easily accessible, and relatively cheap coal, together with standards of living unknown elsewhere in the world, all attempts, either experimental or commercial, to utilize the fuel value of peat have proved economically unprofitable.

Agricultural use has also proved a disappointment in many areas in this country; only utilization of high-lime peats in favored locations has been even moderately successful. Working against the producer is the fact that, not only must the land be drained before it can be used, but it also requires heavy fertilization, since all peats are deficient in potash and phosphate. A further liability is excessive frost hazard, resulting from the occurrence of peat in depressions or on flat land with poor air drainage. Under these handicaps, only hay crops and hardy vegetables can be grown to advantage. But the market for many such vegetable crops is limited and likewise often far from the producing area. Further, garden crops require much hand labor, distasteful to the average American farmer though not to the European. One crop which would appear to be a possibility and one grown rather commonly, is the potato. Even with this crop, however, there are the dangers of summer frosts and flooding, which sometimes produce a total crop failure. Moreover, the grower is handicapped by consumer preference, since the average housewife, the purchaser, prefers potatoes grown on sand land, in the belief that they are of superior quality. Though this is not necessarily a fact, it still makes it difficult to market the crop at a satisfactory price.

Soil Classification. Until about 1910, classification of mineral soils was based on the type of parent material from which the soils were derived, and upon whether they were formed by decomposition of the underlying rock in place, that is, from residual material, or from material which did not originate in place, but was transported. With such a basis for classification, soil and surficial geology maps were essentially the same.

With further study, which has accompanied recent developments in pedology, or soil science, it has become apparent that some of the more important characteristics of normal soils are not determined by the type of material, but result from climatic, vegetation, topographic, and age conditions. The older classification has therefore passed out of use and has been superseded by one based on such characteristics of the soil profile or section as color, texture, maturity, and chemical conditions with respect to lime accumulation. In view of the fact that so many environmental factors affect the character of soils, and that adjustments to soils are specific, there is no better single indicator of environmental conditions in their entirety than that supplied by soil types.

Except under desert, swamp, and tundra conditions, soils change from the surface downward, three more or less distinct zones or horizons being recognizable in a section such as a roadside cut. Beginning at the surface and extending downward anywhere from a few inches to a depth of a foot or more, is the "A" horizon, dark and sometimes black in color because of the large accumulation of organic matter. In this horizon, the maximum amount of change has occurred, for it is the oldest. Consequently, oxidation, or union with oxygen; leaching, or removal of soluble minerals; and eluviation, or mechanical displacement downward of fine material by water, have been most extensive. The second, or "B" horizon, consisting of less altered material,

may be illuviated, or have its pore spaces filled by the fine material carried down from the "A" horizon, even to the extent that a hard, compact layer or "hardpan" develops. The "C" horizon, the third, is composed of the parent rock material.

Soils with normal profiles are subdivided into major groups on the basis of lime content and accumulation: (1) the pedalfers, or nonlime-accumulating soils of better watered areas; and (2) the pedocals, or lime-accumulating soils of regions of deficient precipitation, or semiaridity. This, it will be noted, is a division based on differences resulting from climatic conditions, not on type of parent material. The pedalfers and pedocals are subdivided on the basis of other physical characteristics which result, not only from the character of the parent material, but as well from temperature, precipitation, drainage, and vegetation conditions in the areas of their occurrence, since these environmental factors are reflected in soil characteristics. A soil classification on this basis, with a brief statement of areas of occurrence and characteristics of the profile of each of these subtypes, will be found in the Appendix, Chap. LII.

Soils of grassland and forest areas differ in agricultural desirability, and the same is true for the soils which develop under different types of forest and grassland cover. Thus soils of the grasslands are on the average better than those of forested areas; the soils of areas with coniferous forest are poorer than those of areas with hardwood forest; and the soils of the steppe or dry grasslands are not so good as those of the more humid prairie regions. The reasons for this will, in considerable part, be evident after a study of the profiles and descriptions of the various soil types listed in the Appendix, Chap. LII. So long as agriculture was confined to forested areas, production was therefore limited and extensive mechanization was impossible. Only with expansion of agriculture into the fertile prairie and the better watered steppe grassland areas was large-scale production with extensive use of machinery a possibility, and not until then did food become abundant and cheap, and the fear that population would outstrip food supply disappear. Today, however, as a result of soil misuse, this again looms as a possibility.

Soil Misuse. Our soils are a national heritage which should be conserved, but this desirable end can be attained only by certain fundamental modifications of our past attitudes and performances. Problems of present soil misuse are most apparent and serious in cutover and hilly regions of the South and East, where occupation has been longest, but they are likewise present in our range land, our dry farming and irrigated areas, and in swamp regions which have been drained unwisely. Even the best of our farm land presents some which deserve immediate attention.

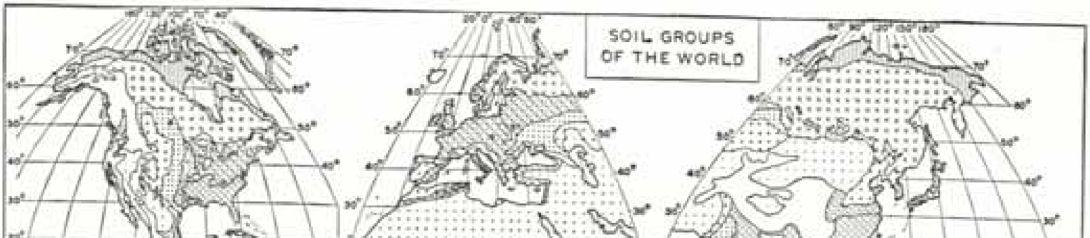

FIG. 122. Soil groups of the world. (After Marbut, Kellogg, Wolfanger, and others.)

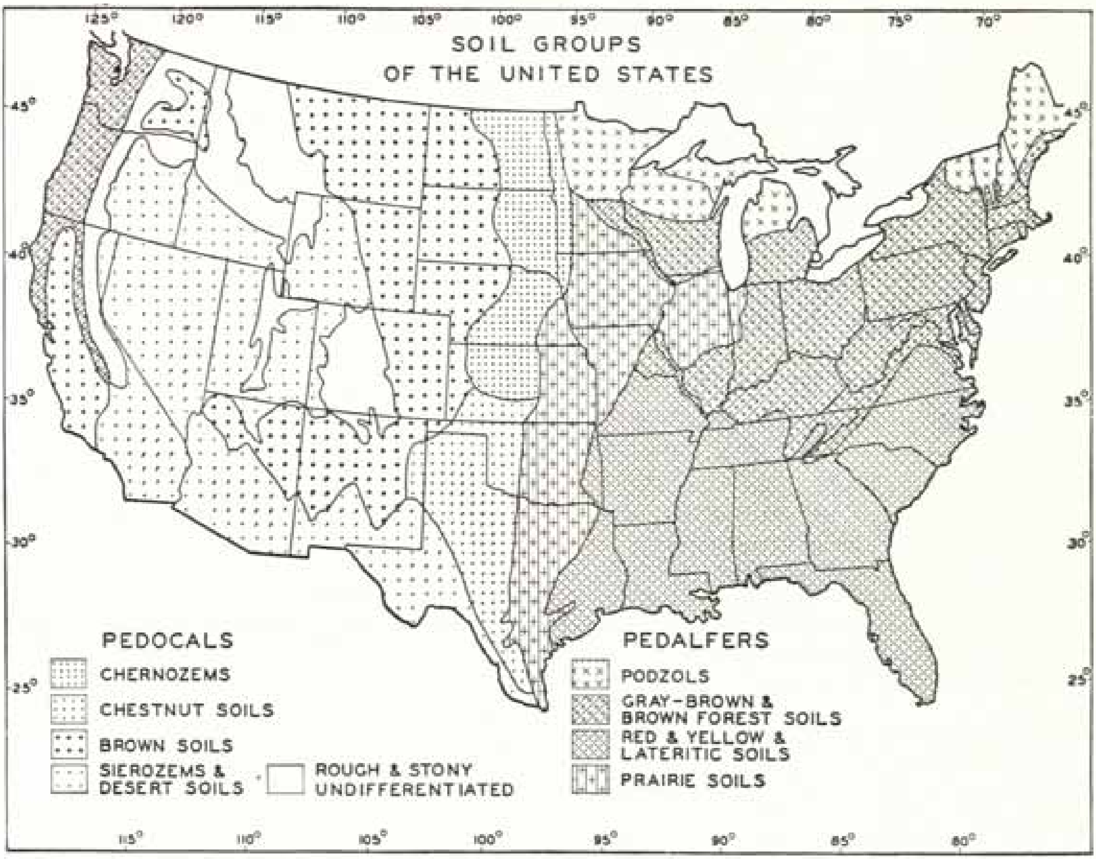

FIG. 123. Soil groups of the United States. (After Marbut, Kellogg, Wolfanger, and others.)

Part of the misuse of our soils results from ignorance, but a larger part stems from social and economic conditions. The long prevalent belief that land was unlimited in amount led to early grants, which were virtually presents, of large acreages to both individuals and corporations. Subsequently, land speculation and use followed in which the principal profit was from increase in land prices which occurred when free land was exhausted. In farm practices, therefore, the immediate return was of paramount importance, this being intensified by the necessities of a large and increasing tenant population, these two, singly or in combination, producing conditions so critical that realities must finally be faced or disaster is inevitable.

Individual initiative, plus hasty and poorly conceived legislation, have within less than a century cooperated to produce results which can no longer be ignored, if the future is to be assured. Present palliatives such as aid to distressed areas, whether in cutover lands or the Dust Bowl, merely perpetuate and intensify existing undesirable conditions, already almost intolerable in those areas. They are only anodynes which temporarily relieve but do not remove the cause and produce a cure; they may serve certain ends, but not the interest of the country, for they do not eliminate agricultural slums.

To solve the problem will necessitate taking a long-time view, and a program of education, both for the farmer and the general public. It can be solved only by putting the land to its best use, whether in forest, grazing, or agriculture, and by following practices in such uses which will eliminate unnecessary and undesirable changes in our soils. For an extended discussion of measures necessary to secure these results, the student is referred to the selected reading list at the end of this chapter.

QUESTIONS AND EXERCISES

1. What is soil? How are soils formed? Of what are soils composed? What percentage of an ordinary mineral soil is mineral matter? What factors determine the agricultural desirability of soils?
2. Why may normal erosion be beneficial to soils? Why is this particularly true in the humid tropics? What is meant by accelerated erosion? How far back in history has accelerated erosion been a problem?
3. What are the more important causes of accelerated erosion? How does it affect crop yields? Why? How extensive is this type of erosion in the United States?
4. Into what classes are soils divided on the basis of texture? What is a warm soil? A cold soil? A heavy soil? A light soil? For what uses are warm, light soils best adapted? Why? What is a loam? Are all loams fertile? Why? What are colloids and what is their function in soils?
5. What is meant by the tilth of a soil? What structural condition of soils is most favorable for agricultural production? Why? What steps can be taken to ensure this favorable structural condition?
6. In what mineral plant nutrients are soils frequently deficient? What is the function of each of these, and how are they supplied if they are lacking in a soil?
7. Why is the American farmer sometimes characterized as a soil miner? Why will crop yields never decrease to zero, even under a system of continuous single cropping? Why may single-crop agriculture prove unprofitable, even though this does not occur?
8. What are the common limitations of soils derived from residual material? Why are soils of arid and semiarid areas often of high fertility? What effect does application of irrigation water have on soil texture in such areas, and how does this affect agriculture?
9. What are the four agencies competent to transport soil-forming material? Which of the four operate in your home area?
10. What is alluvium? What is the texture or grain size of this material? What is the general distribution of alluvial deposits of various grain sizes with reference to the stream channel? Why? Why are soils derived from recent alluvium commonly of high productivity? Why are those derived from older deposits less desirable?
11. What name is applied to the soil-forming material transported and deposited by glacial ice? How does it vary in texture? Why are soils derived from till frequently very productive? From what handicaps do soils derived from till sometimes suffer? Why are soils derived from the older tills less desirable than those formed from the younger tills?
12. What are the sources of lacustrine deposits? In what area do important deposits of this material occur in the United States? How desirable are the soils derived from such deposits? From what handicaps do they suffer?
13. In what types of location do sand dunes occur? Why? Of what economic value, if any, are such dunes? What is loess? How do the Chinese make use of one of the peculiar characteristics of loess? Where are some of the great loess deposits of the world found?
14. What names are applied to areas covered with organic soils? What are the two types of organic soil? What is the distinction between them? What are the topographic and climatic conditions favorable for peat accumulation? Why is there little peat in either very high or low latitudes?
15. What are the major classes of peat? How do they compare with respect to desirability for various uses? What handicaps always confront the farmer who operates on peat soils? Why is the American farmer generally averse to the type of production possible on peat soils?
16. How were soils formerly classified? On what basis are they classified today in this country? Why are soils an excellent indicator of the sum total of environmental conditions? What is a pedalfer? A pedocal? What are the differences in the conditions under which the two develop?
17. Compare the soils of grassland and forested areas, and those associated with different types of grassland and forest cover, with respect to relative desirability for agricultural use. How and why did agricultural invasion of the grassland area produce a revolution in agriculture in the Western world?
18. Discuss the abuse of our soils and the problems arising from such abuse.

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This encyclopedic discussion of the manifold relations of man to soils is of value for reference only. To determine the sections of interest, consult the table of contents.

Chapter Seventeen

INLAND WATERWAYS AND NAVIGATION

Extent of Use of Rivers for Navigation. Use of rivers and other inland waterways as highways varies, both from place to place and from time to time, in any given locality. In undeveloped and sparsely inhabited areas such as the Amazon basin, where there are virtually no rail lines and where roads are seldom if ever more than rough trails through the virgin tropical forest, rivers afford the only practicable routes of travel, except for relatively short distances. Some densely populated areas also lack other satisfactory highways and their inhabitants depend on rivers. For example, the Yangtze affords the only effective means of access from the seaboard to the western provinces of China. Likewise, in highly developed areas in Europe, where populations are dense, the volume of goods to be moved great, and various means of moving this freight can be employed to advantage, rivers such as the Rhine, Danube, and even many smaller streams have been improved and brought into more or less effective use to supplement other types of transportation.

In our own continent, the extent of use of rivers has varied with both place and the passage of time. During the Colonial period, French exploration and exploitation of the fur resources of the interior were made possible by use of a system of waterways unrivaled elsewhere in the world. By contrast, the English, blocked by French occupation, and likewise confined to the seaboard in the absence of effective means of inland penetration by river, turned to agriculture, maritime pursuits, and small-scale industry to secure a livelihood. With relinquishment of French control of the interior, however, and especially after the American Revolution, settlement spread from the Atlantic seaboard to the area west of the Appalachians, much of the movement of population being at least in part by river. A favored route for the migration was down the Ohio from the present site of Pittsburgh, thence up some of its tributaries, or from some point of debarkation on the Ohio, overland to the destination. Rivers maintained their importance as highways until after the Civil War, since rail service was poor and most roads were hardly worthy of the name until later. During this early period, St. Louis was a larger city than Chicago, because rivers, which for many years carried most of the passengers and freight, focused on St. Louis rather than Chicago. Subsequently, with improvement of railroads, rivers fell into increasing disuse, except in areas not served by rail lines. By 1930, this change had gone so far that St. Louis, which was four times as large as Chicago in 1840, when rivers were the major highways, was only one-fourth the size of Chicago, a more important present-day focus of rail lines. Of late there has been increasing interest in the possibility of improving and employing our rivers to a greater extent for use in navigation, and in thus restoring to them some of their former significance in our transportation system.

Conditions under Which Improvement of Rivers for Navigation Is Desirable. There is a general popular belief that improvement of rivers for navigation is always, or at least generally, desirable. This erroneous belief is based in part upon the successful use of some improved European rivers, and in part upon the importance of rivers in this country in earlier times, even though under conditions very different from those of the present.

Before any river is improved for navigation, however, a careful study of the conditions of the particular river and of the area to be served should be made. Under no circumstances should

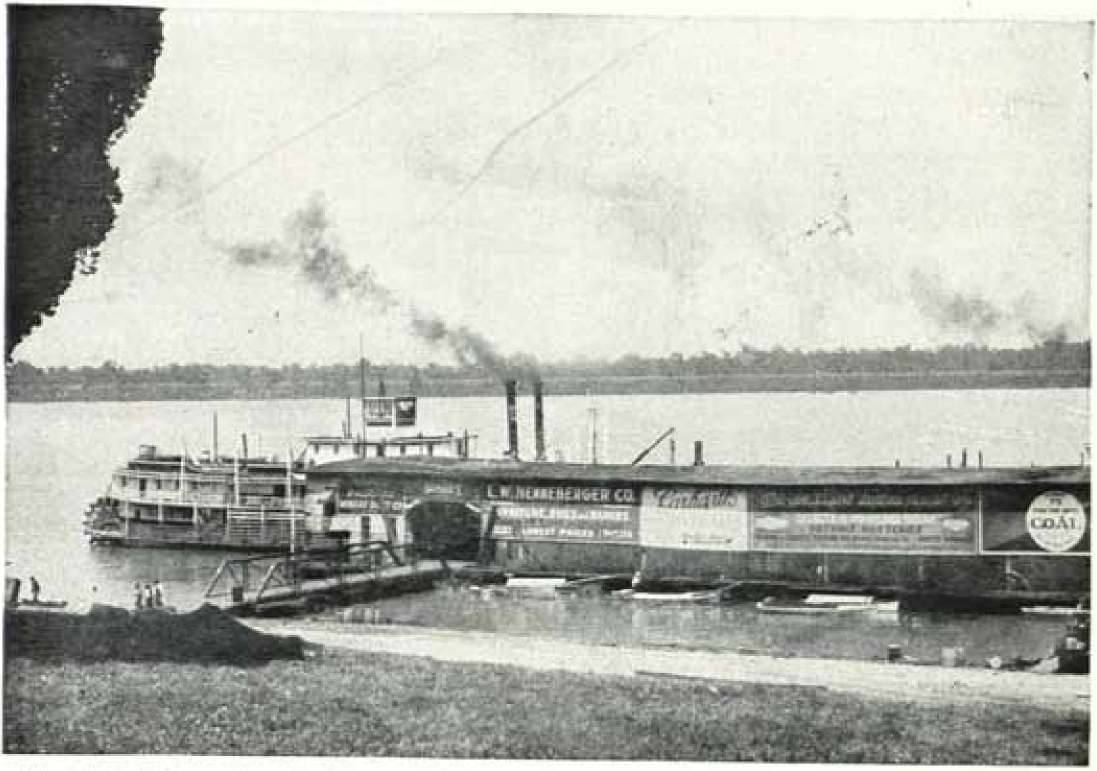

FIG. 124. Dock and packet boats, Paducah, Kentucky. The Ohio River varies so much in volume of flow that a floating dock, which rises and falls with the river, is necessary. The stern-wheeler packet boats at the dock serve the area drained by the lower Cumberland and Tennessee rivers, where other means of transportation are inadequate.

it be a study of some other river and some other area and, certainly, if the river to be improved is in the United States, not one of some river and area in Europe. One factor which should be considered is whether there is any freight to be moved and, if so, whether the amount is sufficient to warrant river improvement. A second is whether the freight will move by water, for it is frequently true that a river is virtually unused, even after improvement, freight still moving by rail, even though river transportation is available. A third, and possibly the most important of all, is the effect river improvement will have on other forms of transportation. Since there is only a definite amount of goods to be moved, unless river improvement opens up new sources of freight, adding another means of transportation merely divides the traffic among a greater number of carriers, to the disadvantage of all, and often to the detriment of the communities served. A fourth fact to be considered is the expense involved. Given sufficient money, it is, of course, possible to improve almost any river so that it can be used for navigation, but it frequently happens that the benefits derived from such improvement are not sufficiently great to warrant their cost. In the final analysis, improvement of rivers for navigation is desirable only when the volume of freight to be moved is sufficient to employ all available means of transportation profitably, and in case the expense involved is not all out of proportion to the benefits derived.

Physical Conditions of Rivers as They Affect Use for Navigation. Whether improvement of a given river is desirable depends in considerable part on the physical characteristics of the stream: direction of flow, depth and stability of channel, variability of volume, gradient, extent of meandering, and the amount of interruption by ice, since these affect both costs and extent of use after improvement.

Many rivers otherwise desirable for use in

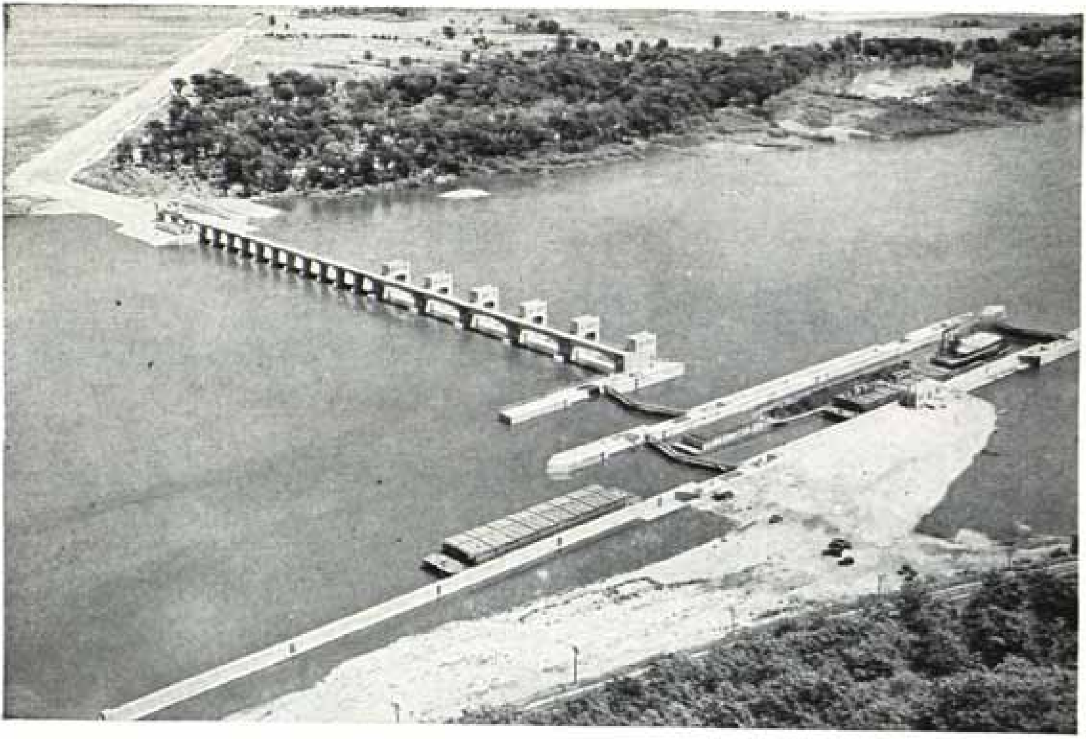

FIG. 125. Dam 7, near La Crosse, Wisconsin, on the Upper Mississippi River, with lock and tow at the right, June 9, 1937. This dam is one of several designed to ensure adequate channel depth; the lock enables tows to pass the dam. Note the rail line, which also carries freight, in the foreground on the Minnesota side of the river; a second, not shown, parallels the river on the Wisconsin side. (Courtesy of the U. S. Engineer Office, War Department.)

navigation, insofar as their physical characteristics are concerned, are of little present value and hold forth no promise of greatly increased future importance because they flow in the wrong direction. Obviously, there is no good reason for improving a south-flowing river to carry freight which moves east, since it will have little if any effect on the direction of flow of trade.

Every river consists of slack water stretches of some depth, separated by shallows, which determine the effective channel depth. If these latter portions of a stream are too numerous, or the water in such stretches is of too slight depth, the cost of improvement may be prohibitive. Further, though some rivers have channels which vary but little in location and depth, those of others change frequently or are blocked by silting after every flood stage, necessitating constant dredging to keep them open for navigation. Such streams are badly handicapped in use, since the changing channel introduces hazards in navigation, and silting entails expense not necessary where the channel and its depth are relatively constant. The rivers of North China, such as the Hwang and the Hai, afford excellent illustrations of the disadvantages of silting and a changing channel.

In many parts of the United States, as well as in other parts of the world, rivers fluctuate greatly in volume. In extreme cases, they may be almost dry during low-water stages yet carry much water when in flood. Such great fluctuations in volume limit effective use to those months of the year during which channel depths are sufficient to permit navigation and may, therefore, make use unprofitable. It is possible, of course, to regulate stream flow by construction of reservoirs to impound flood waters, to be fed into the river during normal low-water stages, but this may cost so much that the benefits derived are not sufficient to warrant the necessary expenditure.

Rivers with steep gradients have swift currents

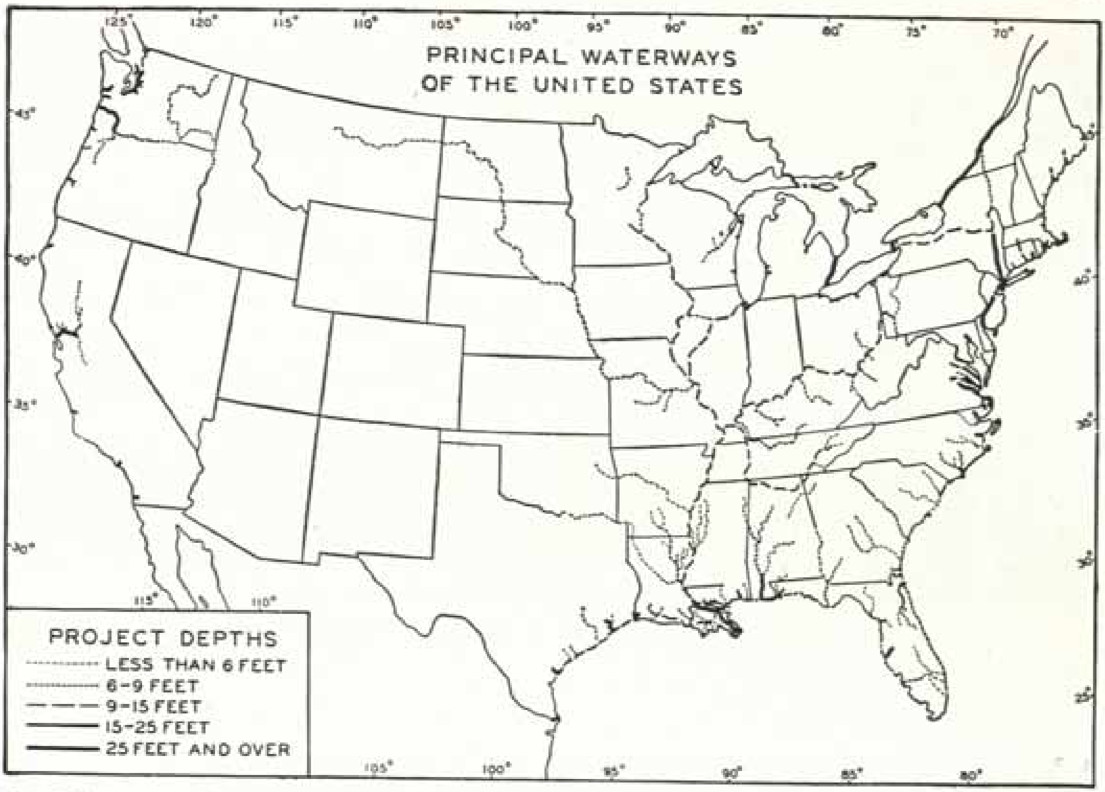

FIG. 126. Principal waterways of the United States. (After the National Resources Board.)

and are often interrupted by rapids and falls. These cause difficulties in navigation which may even necessitate transshipment of freight if it is to move by water, thus increasing costs of river transportation. This necessity may be eliminated by construction of locks, it is true, but the cost is commonly rather high and often too great to be warranted. Further, such locks delay freight movement, and their operation and maintenance involve a continued expense. For these reasons, rivers interrupted by rapids and falls are commonly unused except in young and poorly developed areas and, where used elsewhere, other conditions are sufficiently favorable to offset the handicap.

Rivers, especially those flowing over relatively flat slopes, seldom follow a direct path between two points, but meander, developing great loops in their courses so that distance by water between two points is much greater than by land. In some cases this increase in distance may be so great as to more than offset any savings resulting from lower rates per ton mile by water. Thus a stream which meanders badly is less desirable for navigation than one without excessive departure from a direct route.

To be used effectively for navigation, rivers should be open throughout the year but, in areas with long, cold winters, they freeze over, often for as much as five months or more each year. This shortening of the season of navigation adds to costs of river transportation and, lessening as it does its dependability throughout the year, is a marked disadvantage to both vessel owners and the communities served.

The ideal river, from the standpoint of its effectiveness for use in navigation as determined by physical characteristics, is one which flows in the direction in which freight moves; one with a deep and stable channel; one of considerable volume which fluctuates little; one flowing sluggishly, but not meandering excessively; and one in which freezing does not interfere with use throughout the year. Such a river does not need improvement and it would find use in any area where freight was available.

Fig. 127. Loading lumber at Portland, Oregon, located on the Willamette River near its junction with the Columbia. The navigability of these two streams in their lower courses makes Portland an inland seaport. (Courtesy of the Portland Chamber of Commerce.)

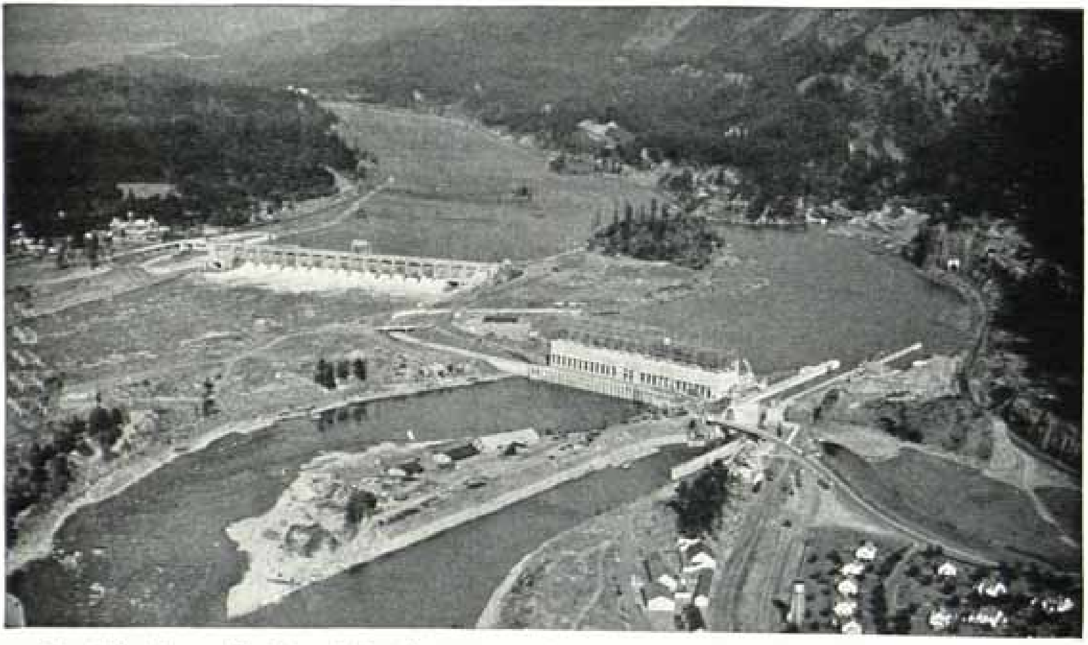

Fig. 128. Bonneville Dam, 140 miles upstream from the sea at the limit of tidal influence, is the first of 10 dams built or planned for the Columbia River. The dam across the main channel of the river is at the left, the Washington side, with a fish ladder at its left end. To the right of Bradford Island, in midstream, is a second fish ladder, the power house, and, at the extreme right, the navigation lock. It will be noted that this is a multiple-purpose project. (Courtesy of the Bonneville Power Administration, U. S. Department of the Interior.)

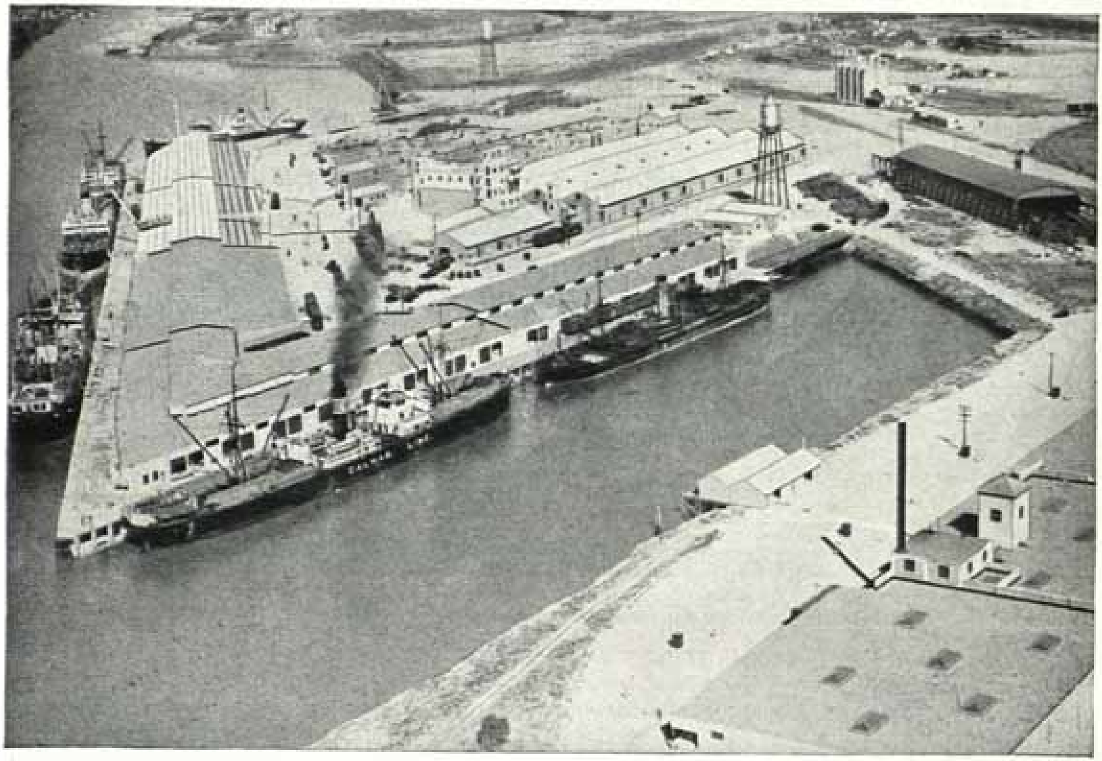

FIG. 129. Port facilities and terminals at Stockton, California, an inland seaport on the dredged lower course of the San Joaquin River. (Courtesy of the Stockton Chamber of Commerce.)

Our Important River Highways. Our major river highways are those afforded by the Mississippi and its larger tributaries, particularly the Ohio, which carries approximately 35 per cent of the river-borne traffic of the United States, with the amount increasing yearly. Most of this freight originates in, and is destined for points within, the Pittsburgh district. The important commodities handled are bulky, with coal leading all others, but with iron, gasoline, and gravel likewise important, these four making up more than 90 per cent of the freight in normal times. The Lower Mississippi River also carries a large volume of freight, including much cotton and similar bulky commodities. Short lower stretches of some of the rivers of the Atlantic, Gulf, and Pacific coastal areas are likewise used extensively but, in such cases, much of the traffic is, properly speaking, in sea rather than river-borne freight, for improved rivers have converted inland cities such as Stockton, California, into seaports. On the Mississippi River and its tributaries, the freight is transported in greater part by large barges, pushed by stern-wheeler towboats. There are few packet lines remaining in operation today, except in areas poorly served by rail. Further, their routes are commonly short; incomes are in many cases in considerable part from tourist trade; and returns are both uncertain and often unsatisfactory.

Unwise Improvement of Our Rivers. Many of our rivers have been improved for navigation unwisely, demonstrated by the fact that in certain cases the increase in freight carried after improvement has been virtually zero, and in many others, it has been very slight. Many illustrations of such hasty and unjustified improvements could be mentioned, but only a few will be cited by way of illustration.

One river improved for navigation, but still not used to any great extent, is the Kentucky, which rises in the coal-mining area of the eastern part of the state. Construction of several dams and locks was undertaken to convert the river into a series of slack-water stretches, with the expectation that coal would move by water with com-

Fig. 130. Freight terminal and terminal facilities, Louisville, Kentucky. (Courtesy of the U. S. Engineer Office, War Department.)

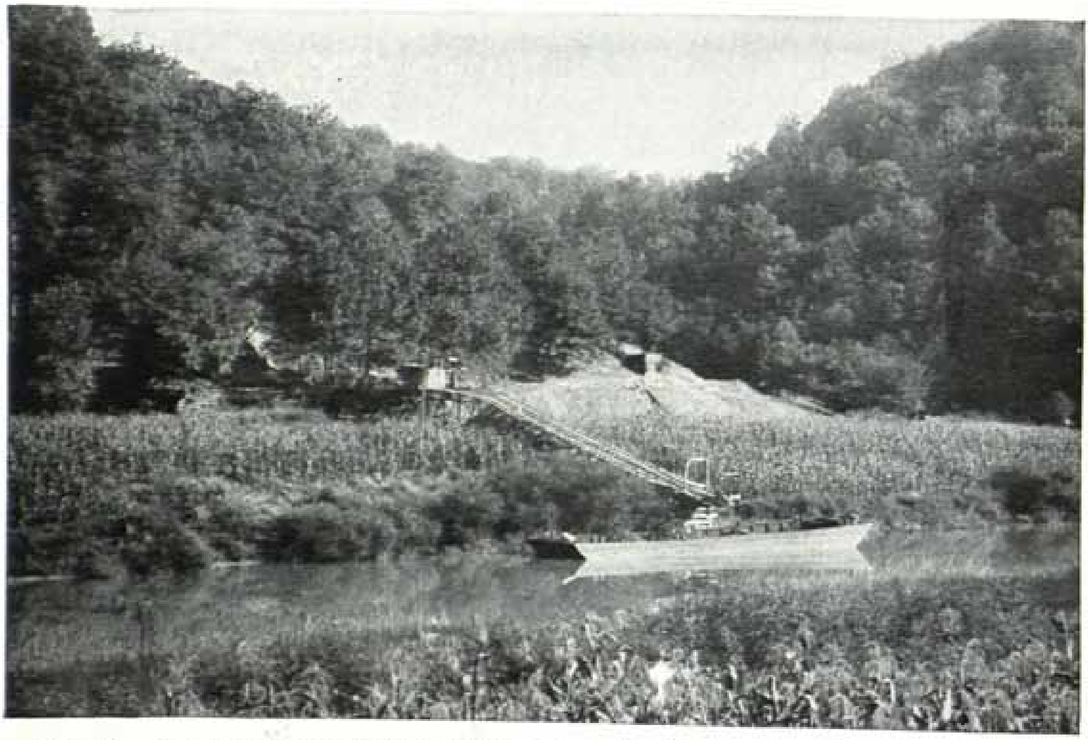

Fig. 131. A coal mine on the Kentucky River near Beattyville, Kentucky. The mine mouth is far up on the hillside, hidden by trees. Coal from this mine, a horizontal shaft into the mountain side, moves by gravity to the waiting barge. Where mines are located as favorably as this, the coal may move by water rather than by rail.

pletion of these improvements. Nevertheless, most of the coal still moves out by rail. Some moves by water, it is true, but that was likewise the case before construction of the dams and locks. The total volume of freight moved by the river today is, in fact, so small that the improvement represents a subsidy of several times the rail rate for every ton of freight moved. Improvement was plainly not warranted on the basis of normal shipments of coal and other bulky commodities.

Another river on which huge sums have been expended to improve its navigability is the Tennessee. Prior to 1930, $19,000,000 had been spent for that purpose, thereby subsidizing the shipping of that date at the rate of 9.8 cents per ton mile, even more heavily than on the Kentucky, to move types of freight, most of which were carried by water before the river was improved. This subsidy was so considerable that it normally represented approximately 90 per cent of the actual value of the freight moved. Yet, despite the results secured by these earlier expenditures, TVA charges "19.8 per cent of its normal multiple-purpose" investment to navigation, ostensibly with the idea that normal freight movement warrants such a charge.

Improvement of the Upper Mississippi and Missouri rivers falls into the same category as do the two preceding examples, and many others of similar character could be listed. As for the Upper Mississippi River improvement, the report of a disinterested, nonpartisan committee appointed to consider the merits of the project was adverse, even though completion of the project was recommended, on the basis of previous extensive commitments. Even the proposed Lakes-to-the-Sea Waterway, today much in the public eye, has been pronounced economically unsound by competent economists who have subjected the project to careful study.

It is apparent from past experience that too many rivers have been improved for navigation without sufficient preliminary study of the facts, or for interested reasons. It is equally apparent to all who consider the question objectively, without personal bias or self-interest at stake, that we can avoid the mistakes of the past only by adopting a different policy in the future.

Lake Navigation. Few lakes are used to any great extent for moving freight, since most of them are small and, even though some are of considerable size, little freight is available for shipment from shore to shore. In many cases, lakes actually obstruct rather than facilitate the flow of traffic by imposing a water barrier in the path of a land route, thus adding to the length of the rail haul or making ferrying necessary. The North American continent, however, is fortunate not only in having 12 out of the 22 largest lakes in the world but also by having 5 of these connected with one another by navigable waterways. Further, this chain of lakes is located in the heart of the continent, where the volume of freight is great, and the types of commodities to be moved lend themselves to shipment by water. The Great Lakes therefore present an exception to the general rule that lakes are of but little importance as carriers of trade, for the fact that they are both large and deep, as well as connected, permits advantageous water shipment of bulky commodities for considerable distances, without the necessity for transshipment. Not only is the continent favored by these conditions, but this country is peculiarly fortunate in that the Great Lakes are so located that we profit most from their availability for use in carrying freight.

Other Factors Favoring Use of the Great Lakes for Navigation. With all the natural physical advantages of the Great Lakes, plus man's improvement of the connecting waterways including construction of canals and locks, the fact that they freeze in winter, thus shortening the season of navigation, would prevent their effective use if it were not for other favoring conditions. One is the fact that several bulky commodities: iron ore, coal, limestone, pulpwood, plus wheat and other grains, are available for shipment in enormous tonnages. In a year of normal production, for example, upwards of 40,000,000 tons of iron ore alone are moved from the Lake Superior ports to those of the Lower Lakes, in addition to more millions of tons of other commodities, both from and to the head of the Lakes. In an emergency, this tonnage may more than double.

Even this would not permit profitable operation of cargo carriers if it were not for the exceptionally efficient terminal equipment of the lake ports, which makes rapid handling and discharge of cargoes possible. This obviates the necessity for extended, unprofitable periods of time spent in port, and enables effective use of the season of navigation in the actual transportation of freight. Thus earnings are sufficient to offset the

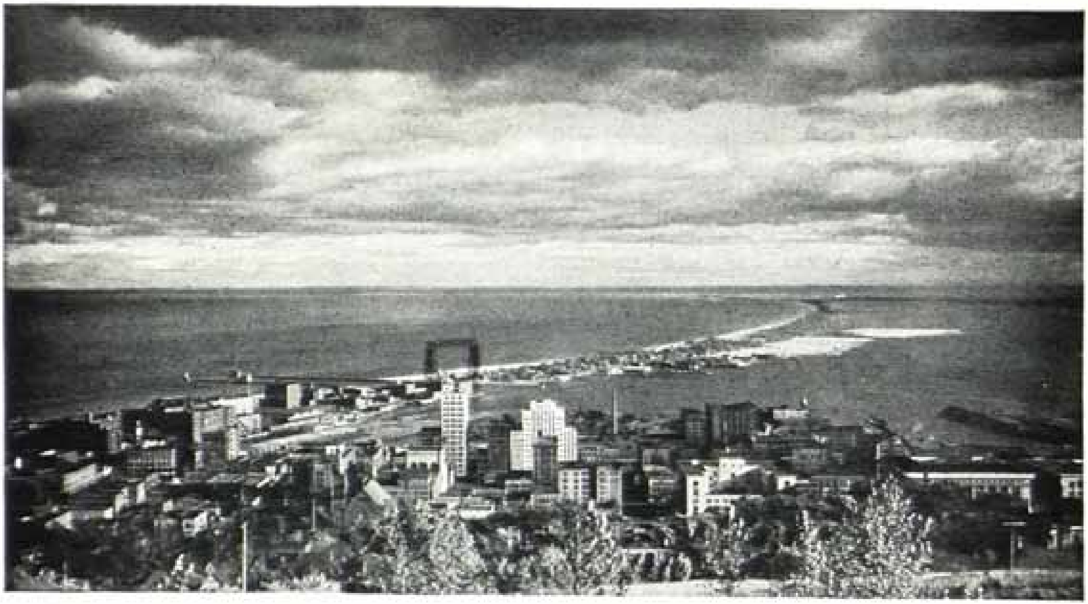

FIG. 132. Looking down on the business section and harbor of Duluth, Minnesota, behind Minnesota Point, a bar across the west end of Lake Superior at the mouth of the St. Louis River. The harbor entrance, with its unique aerial lift bridge, cuts across the bar. Duluth is an extremely attenuated city located on the narrow strip of flat land along the waterfront, with very steep grades on the short cross streets which climb the lower slopes of the upland. (Courtesy of the Duluth Chamber of Commerce.)

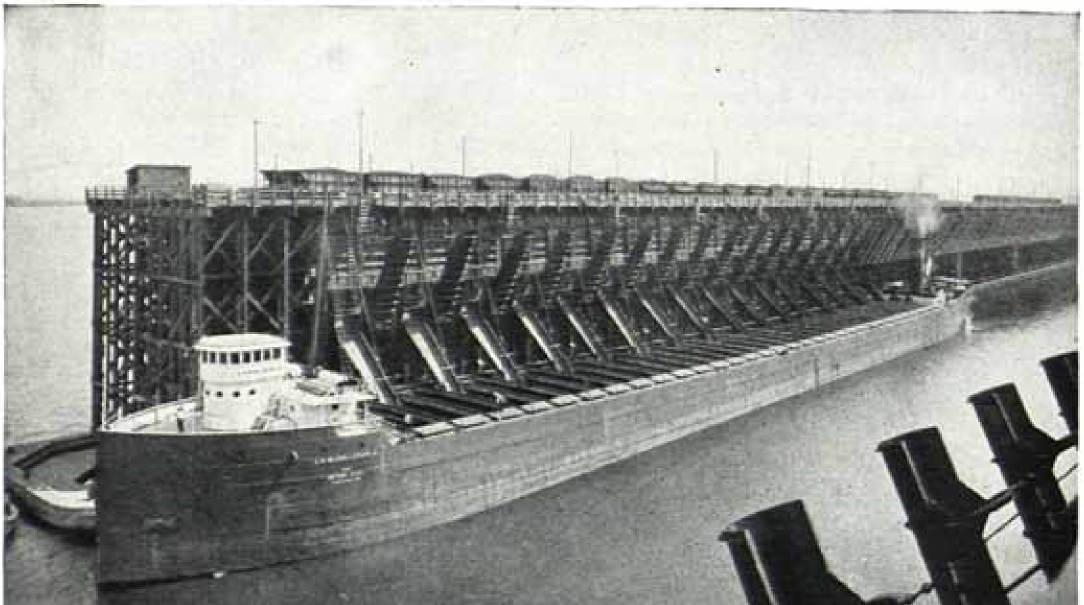

FIG. 133. Loading iron ore at Duluth, Minnesota. The ore slides by gravity from the loaded hopper ore cars on the trestle directly into the hold of the vessel. Though the capacity of the freighter is 14,000 tons, requiring 300 cars for transportation of the necessary ore from the mines, the hold can be filled in 3 hours. (Courtesy of the Duluth Chamber of Commerce.)

lack of revenue during the period of idleness of the winter months. In addition to the port facilities, the cargo carriers themselves are highly specialized in type and of sufficient capacity to permit economical operation. The major portion of the traffic of the Great Lakes is bulk freight; most of the package freight moves by rail, and the same is true for passenger traffic, except for limited excursion trade. Only on the Lower Lakes, particularly between Detroit, Cleveland, and Buffalo, is passenger and package freight traffic important.

Lake Ports. Most of the lake ports have harbors developed by dredging and otherwise improving the lower courses of streams, generally of small size unless connecting two of the Great Lakes, as does the Detroit River. In some cases, these "inner harbors" are supplemented by artificial or semiartificial harbors protected by breakwaters, in the lake proper. The harbor of the port of Duluth at the head of Lake Superior, for example, is a bay back of a bar at the mouth of the St. Louis River; that of Toledo, the lower course of the Maumee; that of Cleveland, the lower Cuyahoga River. Chicago has several harbors: one the Chicago River; another in the lake, protected by a breakwater; others in South Chicago, made by dredging shallow nautral channels and lakes.

Each of the Great Lakes ports presents scenes of considerable activity during the season of navigation. In view of the great importance of the freight trade of the Great Lakes, practically all of the lake ports have developed harbor and terminal facilities for storing commodities to be shipped, as well as for loading and unloading cargoes. Grain discharges from elevators on the harbor front through pipes into the holds of the vessels at the dock and it is removed similarly; iron ore slides down chutes by gravity into the open hatches of the cargo carriers and is removed by great mechanical scoops with comparable

FIG. 134. There are five locks in all at Sault Ste. Marie, between Lake Huron and Lake Superior; four United States owned and operated; one Canadian. The lock shown, completed in 1943 at a cost of \$14,000,000, was built to speed the flow of iron ore to the steel mills. It is 800 feet long, 80 feet wide, 30 feet deep. Raising ships 20 feet from the Lake Huron to Lake Superior level, it can be filled or emptied in less than 15 minutes. To the right are two of the older locks. (Photo by Gordon Coster, Courtesy of *Life Magazine.*)

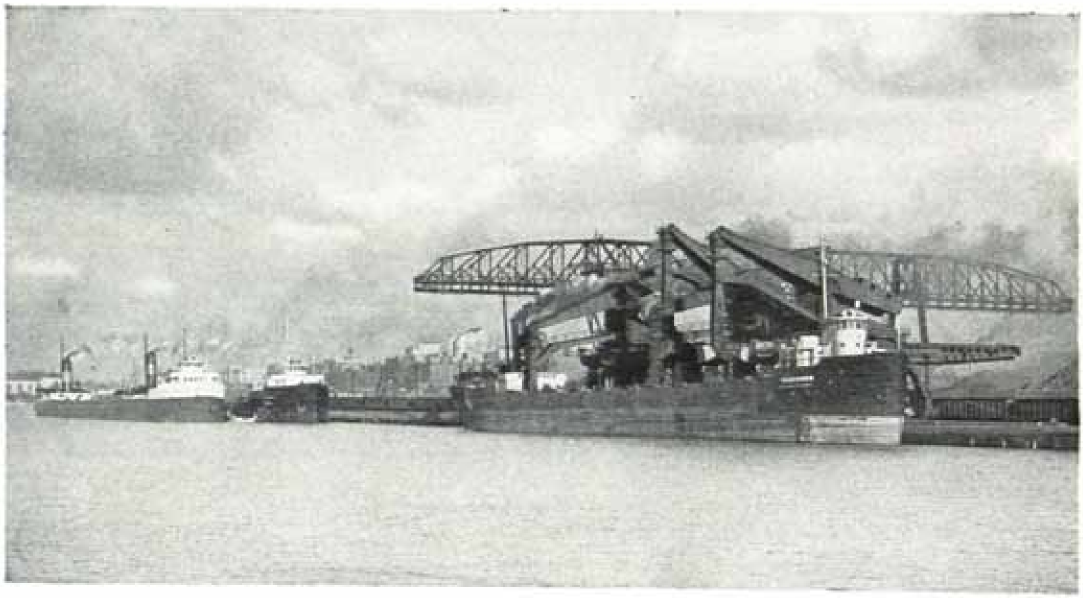

FIG. 135. Typical lake freighters and the unloading of iron ore, Cleveland, Ohio. The vessel in the foreground is discharging cargo, the ore being transferred to the waiting cars by means of the great mechanically operated cranes and shovels, shown in use. (Courtesy of the Cleveland Chamber of Commerce.)

rapidity. Some of these processes of loading and cargo discharge, together with a view of a typical lake port, are shown in the accompanying illustrations.

The inhabitants of many of the lake ports believe that completion of the Lakes-to-the-Sea Waterway would transform them into important ocean ports. However, before accepting this as a fact, it is well to remember that enormous expense would be involved in deepening not only river channels but harbors as well; that navigation would still be limited by ice to part of the year; that navigation hazards are greater on narrow waterways than on the open ocean; and, last but not least, cargoes for both inbound and outbound passage would be difficult to secure.

Canal Navigation. Not only does man use unimproved natural waterways and increase their desirability for use in carrying traffic by improvement, but, by channel rectification and dredging, he also converts some into canals, largely artificial waterways, but dependent for their water supply on rivers and lakes. In some cases, by linking and improvement of rivers in different drainage basins, he has evolved water highways of considerable length and, occasionally, of appreciable value. Such canals are, in all essential respects aside from the artificial characteristics imposed by improvement, part of the system of natural interior waterways.

Early Canals in the United States. With occupation of the region west of the Appalachians, not only were rivers pressed into use, in the absence of more effective means of transportation, but several canals were built. The first and most successful of these, the construction of which may have been prompted in part by the returns from shorter, earlier ventures along the seaboard, was the 363-mile long Erie Canal. This was completed in 1825, before the advent of railroads, at a total cost of slightly more than $7,000,000. By present-day standards, this 4-foot ditch, 28 feet wide at the bottom, would be regarded as inadequate, but in its day it was one of the most important agencies in ensuring prosperity to the Middle West, for it reduced freight rates between Buffalo and New York from $100 to $10 per ton. Not only were shippers benefited, but tolls yielded sufficient returns over the effective life of the canal to repay the original cost nearly sixfold, and to nearly equal all sums spent for later improvements. Traffic increased so rapidly that it was enlarged twice: first to a depth of 7 feet and a bottom width of 52.5 feet, between

1836 and 1862; and, subsequently, to a depth of 9 feet in some sections, between 1884 and 1898. In its later history, railroad competition cut into the canal trade so heavily that tolls were abolished in 1862 as a means of increasing use. Despite this, traffic still continued to decrease until, by 1900, the volume of freight carried was negligible.

The Erie Canal was successful, in the absence of rail competition, because of the natural conditions which enabled it to tie deep-water navigation of the Great Lakes with that of the Atlantic seaboard by way of the Hudson River. Its success tempted the construction of several other canals which followed less favored routes over greater elevations, to connect small rivers of the Atlantic seaboard with tributaries of the Mississippi. The Erie Canal was an all-water route; the others were interrupted, barges being hauled by inclined planes over the divides. None of these latter ventures was highly successful; many were complete failures.

In the Mississippi Valley as well, there was a similar epidemic of canal construction during the same period, designed to link the Great Lakes with the Ohio or the Mississippi. The most important of these "improvements" was the Illinois and Michigan Canal, a 100-mile waterway connecting Lake Michigan with the Illinois River. This was begun in 1836, but was not available for use until 1848. Its opening diverted the trade of the Illinois Valley from St. Louis and downriver ports to Chicago, and was an important factor in that city's growth between 1850 and 1860. By the latter date, rail competition had made such serious inroads on its waterborne traffic that this influence was no longer significant and, though the canal or its successor is still in use, its importance is slight. Canals connecting the Ohio and the Great Lakes have today disappeared almost completely; some have even been filled and diverted to other uses. In all, it is estimated that 4000 miles of these partially artificial waterways have passed out of use completely, with the wiping out of an original investment of possibly as much as $200,000,000.

Present-day Canals in the United States. Outstanding among our canals of today are those of the New York State Barge Canal System, the expanded 525-mile successor of the old Erie Canal. Brought into existence as a result of increased interest in water transportation, it was completed and opened for use in 1918 at a total

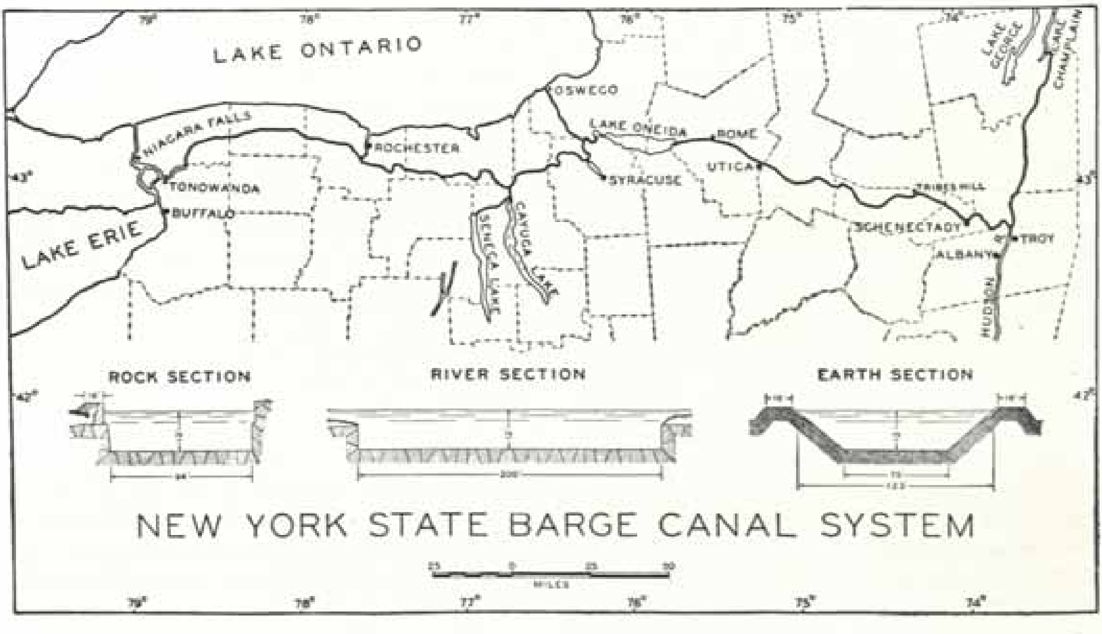

FIG. 136. Map of the New York State Barge Canal System, and sections through different parts of the Erie Division. (After Division of Canals and Waterways, State of New York.)

FIG. 137. Motorized steel oil barge in Lock 12, Tribes Hill, New York State Barge Canal, Erie Division. (Courtesy of the Department of Public Works, State of New York.)

cost, including terminals, of $177,000,000, to which should be added an additional $25,000,000 expended for further widening of the narrower parts of the channel.

This modernized version of the Erie Canal is suitable for use by large barges, for the minimum depth of the 350 miles of the Erie Division, as well as over the sills of its locks, is 12 feet, and each lock accommodates vessels with a length of 300 feet and a beam of 43½ feet during the eight months of the year the canal is open for use. Terminal facilities, constructed at a cost of slightly more than $26,500,000, are excellent, including two large, modern grain elevators: one at Oswego, the other at Gowanus Bay, Brooklyn.

Despite these favoring conditions, the amount of freight moved in normal times is relatively small, varying between 3,500,000 and 5,000,000 tons, slightly less than 20 per cent of the capacity and of the amount it was expected the canal would carry. Of this freight, petroleum is most important, followed by grains, sand, stone, gravel, and a long list of items of minor importance, with less than 14 per cent of all goods handled in normal times within recent years originating outside of, or destined for points outside of, New York State.

The canal is operated toll-free, at an annual maintenance cost of from $3,000,000 to $3,500,000, and a yearly debt service charge of $4,700,000: a total expenditure of approximately $8,000,000 each year to subsidize movement of less than 5,000,000 tons of freight in normal times. If tolls to cover all charges were levied, it would eliminate carriers from the canal, for water rates would then equal 122 per cent of those by rail. The somewhat dubious economic soundness of this canal system has led to considerable discussion as to the best disposition to

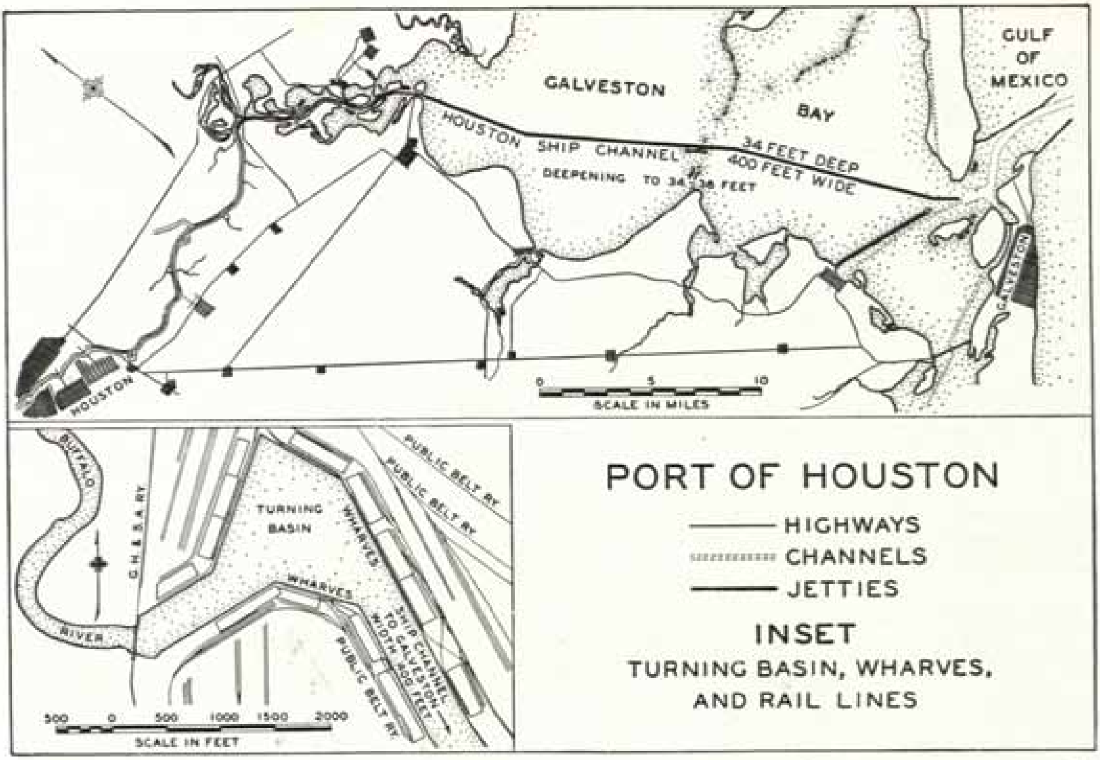

Fig. 138. The port of Houston and its ship canal to the Gulf of Mexico. (After the *Houston Port Book.*)

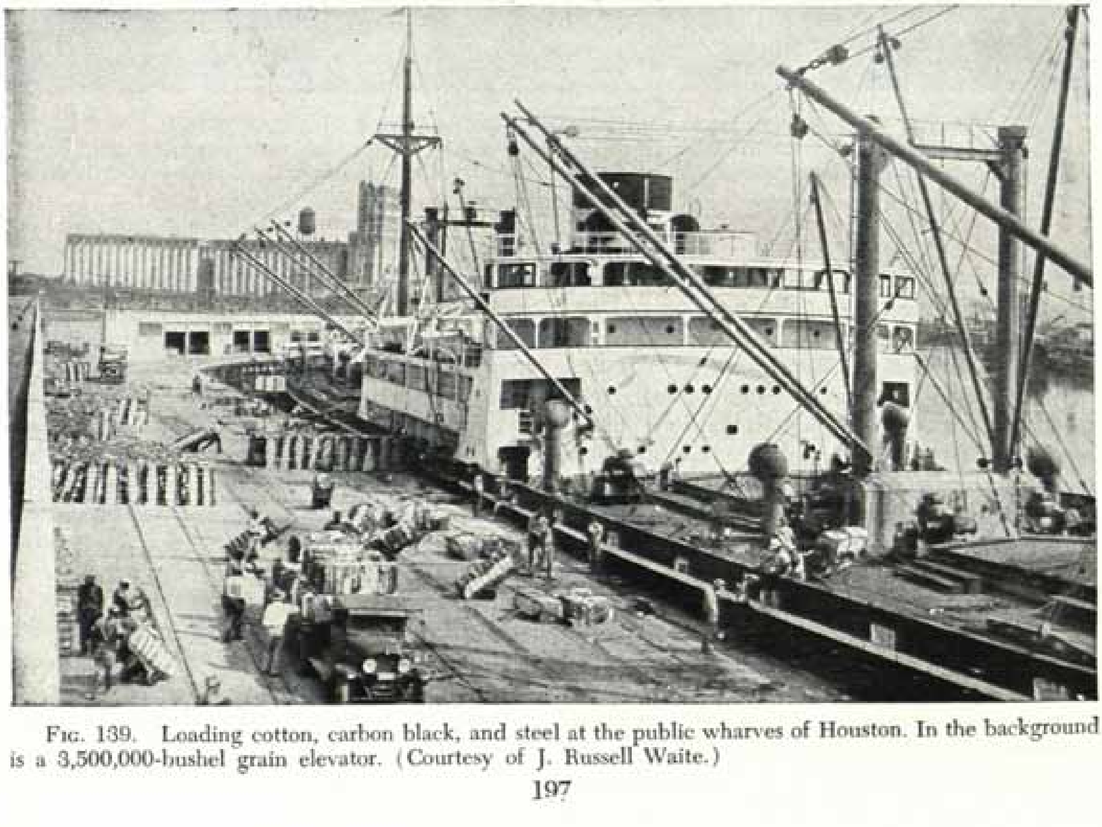

Fig. 139. Loading cotton, carbon black, and steel at the public wharves of Houston. In the background is a 3,500,000-bushel grain elevator. (Courtesy of J. Russell Waite.)

FIG. 140. The canal network north of Amsterdam, Holland. This is the North Holland Canal through the "cabbage country." Since ice interrupts use for only a few weeks, such waterways find use most of the year, boats being generally employed for the carrying of produce to market. (Courtesy of *Life Magazine.*)

be made of this waterway, at present owned and operated by the State of New York, normally at a substantial yearly loss.

The 7-foot deep, 75-mile long waterway, known as the Illinois-Mississippi Canal, with termini at Bureau on the Illinois and Rock Island on the Mississippi River, is the only other barge canal in the interior surviving from an earlier period, aside from canalized rivers. Authorized in 1890, and built at a cost of approximately $12,000,000, it is now antiquated, and carrying charges and maintenance costs equal several times the value of the freight moved. Recently, it has been proposed to modernize this waterway, increasing its depth to 9 or 12 feet, and reducing the number of locks to 10, at an estimated cost of $30,000,000. If this is done, it will afford a direct all-water route from the Chicago area to the Upper Mississippi Valley. Though it is open to serious question, advocates of the improvement argue that benefits to the Central Northwest would justify the expenditure.

Ship Canals. Of a somewhat different type are the ship canals, such as that of the inland port of Houston, Texas, 50 miles from the Gulf of Mexico. Making use of Galveston Bay and the embayed lower course of the Buffalo River, a 400-foot channel with a minimum depth of 34 feet now connects Houston with the Gulf. This made possible a total trade of 25,623,078 tons of freight in 1941, a normal year, thus ranking the city fourth in tonnage among the seacoast ports of the United States in that year. Cotton supplied most of the freight, with petroleum,

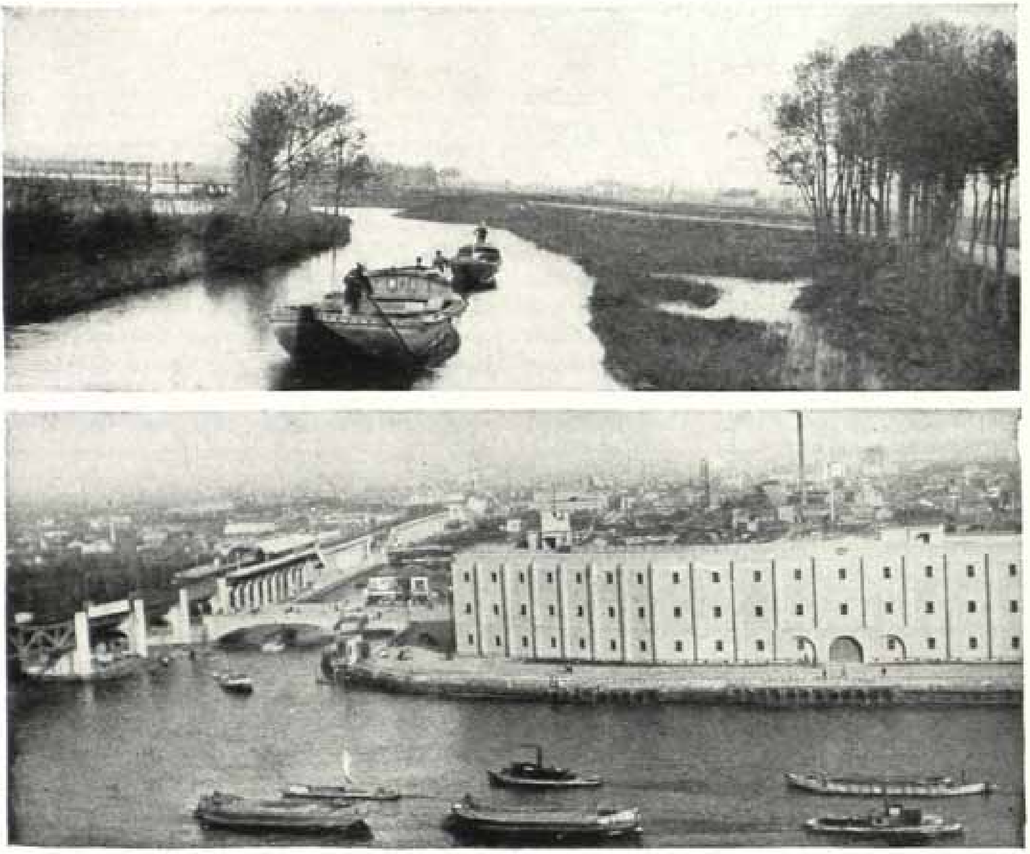

FIG. 141. *Top:* A scene on the delta of the Shinano River, Echigo Plain, western Honshu, Japan. Farmers with cargo boats returning from Niigata, after having marketed their rice, an important crop on the wet land of the delta.

Bottom: A prewar scene on the busy Sumida River, in the industrialized section of northeastern Tokyo, one of the world's great cities. The Sumida is a small stream which has been made available for use by canalization.

grain and other products of considerable importance.

Canals in Europe. Canal construction in Europe began much earlier than in the United States, rapid growth of mileage following invention of the "lock," which made it possible to cross elevations. By 1800, most of the present-day canals of France, Belgium, Holland, and Germany had been built and, shortly thereafter, those of England as well. Though most of these early canals were shallow, many of them were very profitable until rail competition became effective. The first rail lines were feeders, designed to assemble freight for water transportation, but as they evolved into continuous, through freight lines, they gradually captured the traffic, especially that of the smaller and less efficient canals.

In European countries, except for England, canals have not fallen into the disuse which has been their general fate in this country, partly because of nationalization and subsidization, and partly because of more favorable natural conditions, especially in the case of the larger, more important, and most used waterways, which parallel the flow of traffic and terminate at seaboard. This is particularly true in low-lying Holland, where few locks are required, thus decreasing construction and operation costs. Furthermore, the net of canals is so complete in the Netherlands that virtually all towns enjoy water connection with the seaboard, one reason why

approximately 90 per cent of all traffic is waterborne. Even with favoring natural conditions, operation of many European canals is made possible only by subsidies, which reemphasizes the fact that water transportation is not always economically profitable.

Canals in Eastern Asia. In eastern and southeastern Asia, as in western Europe, water transportation is used extensively. In China, this is in part the result of lack of adequate roads and rail lines, and partly because of favoring natural conditions. In the Yangtze delta region near Shanghai, for example, where the country is very flat and there are many natural drainage lines, the canal mesh is much closer than the road pattern of a densely populated agricultural area in the United States. In Japan as well, the delta of the Shinano, on the west coast of the main island, is traversed by numerous canalized waterways which are used by farmers in marketing crops and for moving various types of freight in Niigata, the major urban center of the area. Canals are likewise important in the delta region on the east coast around Osaka, much of the cotton used in the mills of that city moving in by way of the canalized distributaries of the Yodo River. In Tokyo, the Sumida River serves similarly, as it penetrates the industrialized northeastern section of the city.

Interior Waterways and Man. From the preceding consideration, it is apparent that effective interior water highways increase accessibility in both young and relatively underdeveloped areas, either sparsely or densely populated. It is likewise apparent that, in older, highly developed regions, navigable waterways often add to regional desirability. Therefore regional opportunity is in general increased by an adequate system of navigable interior waterways, or rivers and lakes which lend themselves to effective use without too great expense for improvement. From our own experience, however, it is equally apparent that their use for navigation is not justified, except subject to certain limitations.

QUESTIONS AND EXERCISES

1. Why are rivers used more extensively for navigation in the Amazon basin, central China, and western Europe than in the United States?
2. How did river highways facilitate French exploration and exploitation of the resources of the interior of the North American continent during the Colonial period? Why was English occupation confined to the Atlantic seaboard during this period?
3. What routes did early settlement of the interior after the American Revolution follow? Why? Why was St. Louis such a relatively large and important city, and larger than Chicago until subsequent to 1870?
4. What facts should be considered before a river is improved for navigation?
5. State the physical characteristics of a stream which are important in determining its availability for navigation, and state how each of these characteristics affects such use. What would be the physical conditions of a stream of ideal physical characteristics?
6. Why are floating docks in common use at Ohio River ports such as Paducah, Kentucky?
7. Where are our most important river highways located? Why is the Upper Ohio so important as a highway? What types of equipment are used for navigation on our rivers?
8. In what respects has improvement of the Kentucky and Tennessee rivers for navigation been a disappointment?
9. State several reasons why improvement of the Upper Mississippi and Missouri rivers for navigation has probably been unwise.
10. State some objections to the proposed Lakes-to-the-Sea Waterway.
11. Why are most lakes of slight value for navigation? Why are the Great Lakes an exception to this general rule?
12. Describe the terminal facilities of the ports of the Great Lakes. Why are such terminal facilities a great advantage? If lacking, what would be the effect on use of the Great Lakes for navigation? Why?
13. State the history of canal construction in the United States. Why was the Erie Canal more successful than the other early canals? What useful objectives did it serve?
14. Which is the most important of the present-day canal systems of the United States? Why? What bodies of water does it connect? What freight does this system handle? Has this canal met with the success anticipated for it by its sponsors? Why?
15. How has Houston been converted into an ocean port? What freight is handled through this port? In what volume?

16. State the history of early canal construction in western Europe. Why have the canals of western Europe not fallen into the disuse common in the United States? How extensively are canals used in eastern and southeastern Asia? Why is this the case?

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This chapter is devoted to a consideration of our waterways and their utilization. It contains an interesting and relatively detailed discussion of the rise and decline of river and canal navigation in the United States and of the problem of river improvement, presented in such fashion that it supplements the treatment in your text effectively.

Chapter Eighteen

INLAND WATERWAYS AND POWER DEVELOPMENT

Hydroelectric Power. The physical possibility of developing hydroelectric power depends upon a combination of favoring conditions of stream flow and topography. However, the economic feasibility of such development is determined not only by these factors, but by spatial or locational relationships as well, including proximity to both a market for the current produced and coal or some other potential source of cheap power.

This is because average costs of generation comprise only about 14 per cent of the total cost of power delivered to the domestic consumer at the point of use, the other 86 per cent being absorbed by transmission and distribution. Therefore, only in the 14 per cent, the costs of generation, can any saving be made by use of water power. Even though such a saving is effected, it is often more than offset by high transmission costs, for hydroelectric power must be generated where natural conditions permit, whereas power may be developed by burning coal where the power is to be used. Thus, in a locality where coal is abundant and cheap, use of falling water as a source of power may be unprofitable.

In practice, also, it is only under certain relatively unusual combinations of favoring conditions that any saving can be made, even in generation. This results from the fact that hydroelectric installations are commonly more costly than coal-burning plants of the same capacity, such costs varying with the character of the stream and the section of the country. In the North Pacific states, for example, costs per unit of power developed fall to a minimum; in the South Atlantic states, they rise to a maximum. Further, these costs tend to rise in all areas, since only the less promising sites remain to be developed. Thus, including real estate, water rights, and others, they have quadrupled or more between the dates of the first installations and those of the present time. In addition, hydroelectric plants have probably approached the maximum of possible effectiveness; coal-burning plants will continue to increase in efficiency for some time. This will still further decrease any difference between generating costs in the two types of plant. Therefore, though hydroelectric power is sometimes cheaper, it is frequently more expensive than that developed by burning coal.

Stream Conditions as They Affect Power Development. Whether a given stream is of value for use in generating power depends on its: (1) location, (2) volume, (3) variability of flow, (4) amount and character of fall, (5) sediment load, (6) degree of freedom from freezing, and (7) available dam sites.

Hydroelectric power must be utilized relatively near where it is developed. This is particularly true if the amount is small and, even though large, it can seldom be marketed to advantage more than 200 to 300 miles from the place of generation. Thus the location of the stream becomes important in determining whether it can be used to advantage for developing power, its desirability for that use decreasing with increase of distance from the consuming area. Unfortunately, most rivers best adapted for developing power are in sparsely settled areas where markets for power, both present and potential, are limited.

Commercial installations on small streams are economically unsound, for plant and transmission costs are too great to permit profitable operation. Insofar as such streams are capable of effective use, it is only to supply power for individual farms or, at most, to serve the needs of limited near-by areas, where transmission costs are low.

For such use, however, they are sometimes of considerable value.

Variability of stream flow is always a handicap to development of hydroelectric power. If excessive, all possibility of profitable use may be eliminated, even of large rivers, since it seldom pays to utilize much more than average stream flow. Any other practice involves costly storage of a great volume of water and often construction of supplementary coal-burning plants, thereby adding greatly to the expense of generation. Further, floods may cause damage to the generating plants. Thus rivers whose flow is regulated by natural storage basins or lakes, those heading in great swamps which serve as reservoirs, and those rising in snowfields which afford a steady supply of water, are preferable for generating power to those which vary greatly in volume.

If a stream flows sluggishly, it affords limited power possibilities; even construction of a dam may give only a small head of water and enable development of only a small amount of power. But if stream flow is rapid, and particularly if the stream course is interrupted by falls of some height, desirability for power development may be considerable. For this reason, rivers in mountainous areas, though often handicapped by location, are generally better adapted for use in generation of power than are those in areas of lower elevation and lesser relief.

A heavy load of suspended solid material decreases the value of a stream for hydroelectric development. This is because sediment in water passing through a generating plant is objectionable, and, if a dam to store water is necessary, silting or deposit in the quiet water above the dam decreases the storage capacity of the reservoir. Such silting does not need to fill the reservoir completely to destroy its value. Sometimes, indeed, only a small fraction of its storage capacity must be eliminated to make power development unprofitable, for loss of even a relatively small amount of water needed to tide over a period of low water in the river may decrease power output to an extent that continuance of operation is uneconomic. Thus rivers flowing over hard rocks, or with natural settling basins such as lakes in their courses, are preferable to those whose waters carry much silt in suspension.

Rivers which freeze in winter are less desirable than those free from ice, which may obstruct the free flow of water or even cut off the supply completely, in addition to occasionally forming jams and damaging the generating plants.

In case a dam must be built so that power may be generated effectively, a suitable site for such construction must be located. This necessitates the presence of a natural constriction of the valley and an area which can be flooded to advantage, without undue cost for acquisition of land. A suitable foundation or footing for the dam, and valley walls to which its ends can be anchored securely, must likewise be available. Otherwise water will work under, or around the ends of the dam, at some highwater stage and a disastrous flood may result. Not all river valleys afford such sites.

Conditions under Which a Hydroelectric Power Site Should Be Developed. No stream should be used for development of hydroelectric power unless: (1) the physical conditions are favorable; (2) power can be developed more economically than by burning coal or by some other means; (3) returns from the power developed are greater than those resulting from some other values in the stream, such as scenic attraction and recreational use; and (4) a market for the power exists, or can be developed.

The natural conditions which favor power development are practically all satisfied at Niagara Falls, where the volume of discharge of the Niagara River is both great and, regulated by the Great Lakes, relatively constant, varying from 158,000 to 224,000 cubic feet per second. The fall is considerable; to the drop of 150 feet at the Falls is added that of the rapids below, so that a total head of 305 feet is available. The river is also relatively free from sediment, for Lake Erie is an effective settling basin. The only handicap resulting from natural conditions, and that is not serious, is created by freezing.

Not only are physical conditions of the Niagara River favorable, but a near-by market for power is available, the Falls being centrally located with reference to one of the more populous, highly industrialized areas of the United States and Canada. For these reasons, power developed by regulated diversion of water from above the Falls, through penstocks, to the turbines of the plants in the gorge below, is cheap power, finding a ready market and aiding in development of industries which can use electric power to advantage. Unrestricted use of power potentialities available at this site would, however, be

undesirable, despite the favoring natural conditions, for it would destroy the beauty of the Falls. Therefore, as stated earlier, the amount of water which can be diverted from above the Falls is restricted, so that there is only a limited and relatively unobjectionable effect on stream flow and the Falls.

Distribution of Potential and Developed Hydroelectric Power. The United States Geological Survey estimates that 50 per cent of the world's potential water power is in the tropics, with two-thirds of this in central Africa and eastern Madagascar, where precipitation and topographic conditions are very favorable. The remaining 50 per cent is in intermediate latitudes, distributed as follows: two-thirds in glaciated highlands and mountains; one-fifth in other highland areas; and practically all the balance in glaciated plains areas. There are, however, great differences in the location of potential and developed power. In part, this is because of practical limitations to distances of economic transmission; and, again, because development has been most extensive in areas such as Switzerland and the Scandinavian countries, and in New England in the United States, where coal is lacking.

Estimates of potential water power available vary widely because based on different and insufficient data, but it is believed that the total potential water power in the United States, based on stream flow available 90 per cent of the time, with an over-all efficiency in the generating plants of 70 per cent, is 38,301,220 H.P. and, based on flow available 50 per cent of the time, is 53,905,000 H.P. Of these potential totals, 73 per cent is in the Pacific and Mountain states, and 8 per cent in the South Atlantic states. These three divisions, it will be noted, all with extensive highland areas, have approximately 80 per cent of the total potential water power. Development of this power is, however, greater, in proportion to the potential power available, in the northeastern portion of the United States, where near-by markets are available, and where most of the economically profitable sites have therefore been preempted and developed.

For the United States as a whole, water power has come into increasing use during the past two decades. In 1921, the total of such power developed was 7,927,958 H.P.; by 1931, it had increased to 14,884,667 H.P.; by 1935, to 16,075,037 H.P.; and by 1940, to at least 20,000,000 H.P. During the past few years, the larger part of the new development, approximately 80 per cent, has been for public use at public expense. Unless subsidized in similar fashion with money raised by taxation, no great expansion can be expected in view of the limited number of possible profitable new developments.

Some Recent Federal Power Projects. Some Federal projects of river improvement have been undertaken with but one end, such as increasing stream navigability or flood control, in view, but many are multiple-purpose projects, designed to accomplish several objectives. This latter approach to river improvement is obviously preferable, since it tends to eliminate duplication of effort, needless expense, and affords an opportunity for formulating a comprehensive program which will ensure a balanced and effective use of the river improved. In the multiple-purpose projects of river improvement by the Federal government, therefore, not all objectives are of equal importance. In some, improvement is primarily to generate power, or to increase stream navigability; in others, it is to bring land under irrigation, for flood control, or for some other purpose. In the discussion of such projects in this chapter, however, consideration will be limited to a few of those undertakings designed primarily to develop power by use of falling water.

Tennessee Valley Project. In addition to development of power, the principal objectives of this project are improvement of navigation and flood control. But these are only three of a long list which includes reforestation of nonagricultural land, production of fertilizers, prevention of soil erosion, improvement of agricultural practices, and research of various kinds. Obviously, the program is comprehensive in its scope.

During the First World War, construction for development of power was begun at Muscle Shoals, just above Florence, Alabama, the head of navigation on the Tennessee River before the present program of improvement. Though a total of nearly \$50,000,000 was spent, the plant remained idle until after establishment of the Tennessee Valley Authority (TVA), a governmental agency vested with authority to engage in numerous activities, and interested in realizing the various objectives which have been listed, in addition to several others.

As constituted in 1945, the project included 9 dams and reservoirs on the main river, and 12

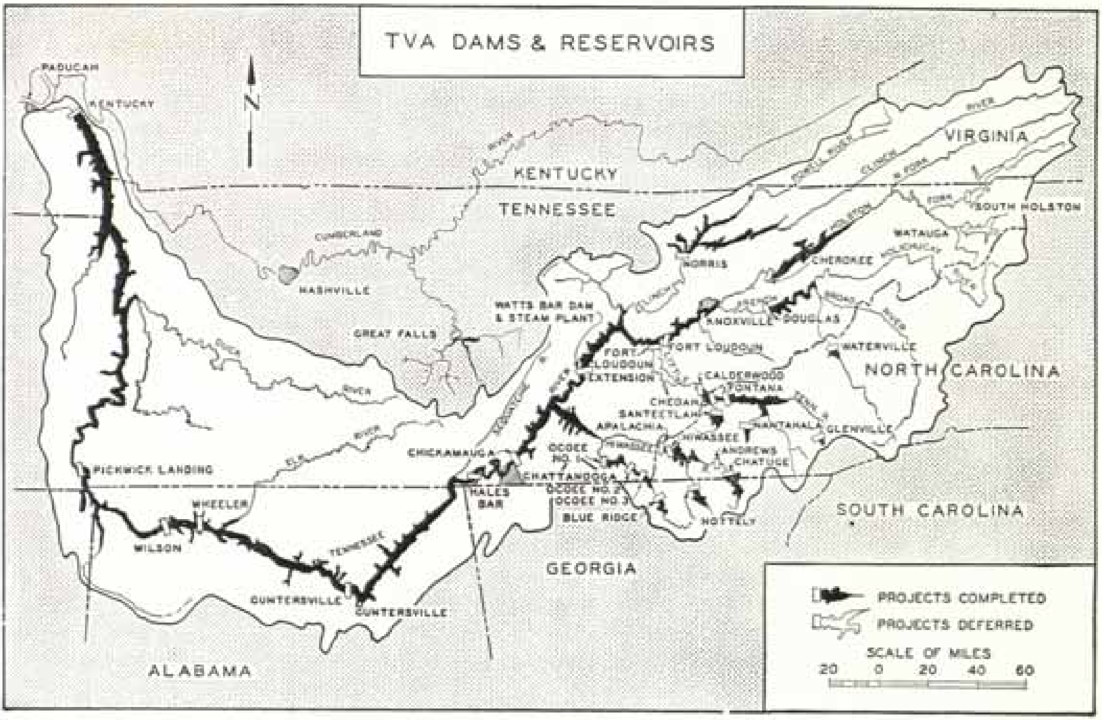


Fig. 142. The area in which TVA operates, and the projects completed and deferred. The reservoirs on the Tennessee permit slack water navigation from the Ohio River to Knoxville, 650 miles upstream, in addition to increasing power development possibilities and serving to control floods. Note the considerable area and the several states served by TVA. (After TVA map of the Tennessee River System.)

on tributary streams. TVA also directs the operation of 5 plants of the Aluminum Company of America on the Little Tennessee River, or a total of 26 installations with a hydroelectric generating capacity of over 2,000,000 kilowatts. These are operated as a unified enterprise. In addition, the Authority has coal-burning plants with a generating capacity of 450,000 kilowatts. These are used to supplement the supply from the hydro-plants, either during low-water stages of the river, or when demand exceeds the amount of power which can be developed, or generated to advantage, at those plants.

According to TVA, "the total authorized program of construction and plant acquisition will involve an expenditure of \$923,181,064." Of this total, the investment in unified system projects will be \$757,015,000. This amount includes \$28,496,000 for steam plants. "The balance of the \$923,181,064, or \$166,066,064, covers power transmission lines and substations, navigation terminals, chemical plants, general plant equipment, and other items." TVA has recently been ordered to repay these costs of power projects and installations to the Treasury of the United States over a period of 40 years, which will eliminate an advantage enjoyed in the past operation of the enterprise.

By use of both hydro-power and coal-burning plants, the unified system of TVA generated 10,117,748,000 kilowatt hours of electrical energy in 1944. This was more than twice as much as in prewar years, when the market for power in the area served was much smaller. If the fiscal year 1944 had been one of normal operations, the multipurpose investment would have been allocated as follows: 65.9 per cent to power; 19.8 per cent to navigation; 14.3 per cent to flood control. Since certain emergency projects were operated primarily for power during this year, however, allocations for navigation and flood control were decreased to 18.4 and 8.1 per cent respectively.

The Tennessee River offers some advantages,

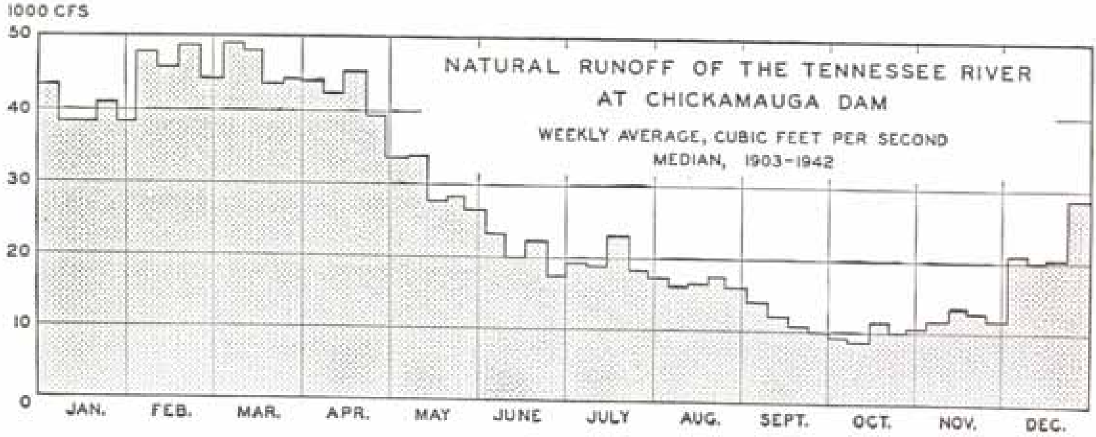


FIG. 143. Natural runoff of the Tennessee River at Chickamauga Dam, between 1903 and 1942. Note the great variation and the season when runoff is least. It is this variability of flow which has made storage of water necessary in order to develop power effectively on the Tennessee River, and to prevent disastrous floods. (After TVA.)

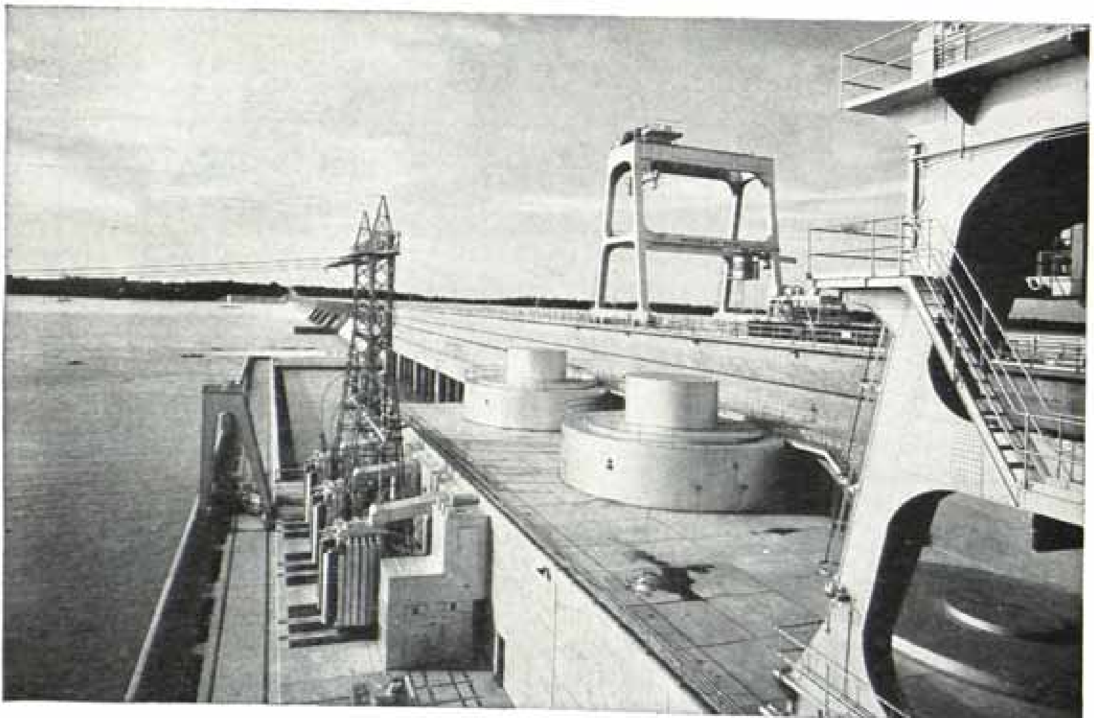


FIG. 144. Downstream face of the completed Wheeler Dam, on the Tennessee River, in northern Alabama. This dam is 72 feet high, 6,342 feet long; the reservoir, which extends upstream 74 miles to the Gunterville Dam, covers an area of 105 square miles. Two 45,000 H.P. outdoor-type generating units show in the powerhouse area at the right; the navigation lock is in the background. (Courtesy of the Tennessee Valley Authority.)

but likewise suffers from certain handicaps in use for development of power. Prior to TVA construction, stream flow varied from a minimum of 4300 in 1925 to a maximum of 460,000 cubic feet per second in 1867, a year of record high-water discharge of the river at Chattanooga. With the present system of dams, the minimum flow has been raised to 25-30,000 cubic feet per second, and the maximum flow of record, 460,000, would be reduced to approximately 250,000 cubic feet per second, according to TVA engineers. It will be noted that, even with the present regulation of stream flow, the variability is still rather great. It is, in considerable part at least, because of this variability of flow that steam plants are necessary, so that the demand for power may be met when reservoirs are low. Though the construction of such plants is desirable in order to use river flow most efficiently, they add to the costs of generation and therefore to the cost of power. At such installations as those at Niagara Falls, where stream flow is regulated by natural reservoirs, the Great Lakes, no such supplementary plants are necessary, which makes generation of power less expensive.

The water of the Tennessee River is muddy, but TVA engineers state that the silt burden has already decreased materially, and, according to the same authorities, sufficiently to make clogging of the reservoirs by deposition no longer a problem of importance.

In addition to storing water for use in generating power, as well as for controlling floods, dam construction has converted the Tennessee River into a series of slack water stretches, extending upstream from the Ohio to Knoxville, Tennessee, a distance of approximately 650 miles. This waterway, usable by vessels with a draft of 9 feet, was employed rather extensively in movement of freight during the war, when all available means of transportation were pressed into service; whether this will continue to be true with the return of normal traffic conditions only the future will disclose, though it is open to question.

Since the normal flow of the Tennessee River fluctuates greatly, control of its floods is of considerable importance, particularly since they affect river stages of the Ohio and Mississippi. In the Tennessee Valley itself, flood danger is greatest at Chattanooga. Though not tested as yet, the storage of 815,000 acre feet on the main river above the city, and of over 4,000,000 acre feet on the upstream tributaries, is believed by TVA authorities to be ample to prevent a dangerous rise of the river waters at Chattanooga. Downstream from the city, a storage of 5,000,000 acre feet, 4,000,000 at the mouth of the Tennessee River, is expected to minimize the danger of disastrous floods in the Lower Ohio Valley. It should be realized, however, that use of the reservoirs for flood control materially decreases their value for storing water to be used for power development.

An incidental benefit accruing from improving the Tennessee River for other purposes has been the creation of artificial lakes with a total area of 936 square miles, and 10,058 miles of shore line. These have added considerably to recreational opportunity in an area lacking in natural lakes. To encourage use of this opportunity, TVA has set aside several tracts as parks, some in forest, and has provided lodges, cabins, picnic areas, and other attractions to tempt tourists.

The merits of this particular project have been the subject of much debate. TVA officials naturally claim it to be economically sound, and most Tennesseans approve of the undertaking, since self-interest is involved. For the country as a whole, however, opinion is divided. Many believe, and honestly, that with a system of accounting similar to that used by privately owned and operated businesses, the project would actually show an annual subsidy of from \$10,000,000 to \$15,000,000 paid by the taxpayers, instead of a profit. Others disagree with this conclusion. Though it is desirable to point out this difference of opinion as to the merits of this venture in governmental ownership and operation, it is not within the scope of this discussion to consider the relative merits of these two points of view, despite the value of such a procedure.

Proposed Valley Authorities. The theoretical soundness of planned use and unified improvement and operation has led to proposals that "Authorities" similar to TVA be set up for other drainage basins, particularly for that of the Missouri River and its tributaries. If it is done for this river system, the enterprise will dwarf TVA, for the area which would be involved comprises approximately 16 per cent of that of the United States. It is as large as Germany, France, and Italy combined, but its present population is less than 12,000,000, and unregulated stream flow poses problems which cannot be

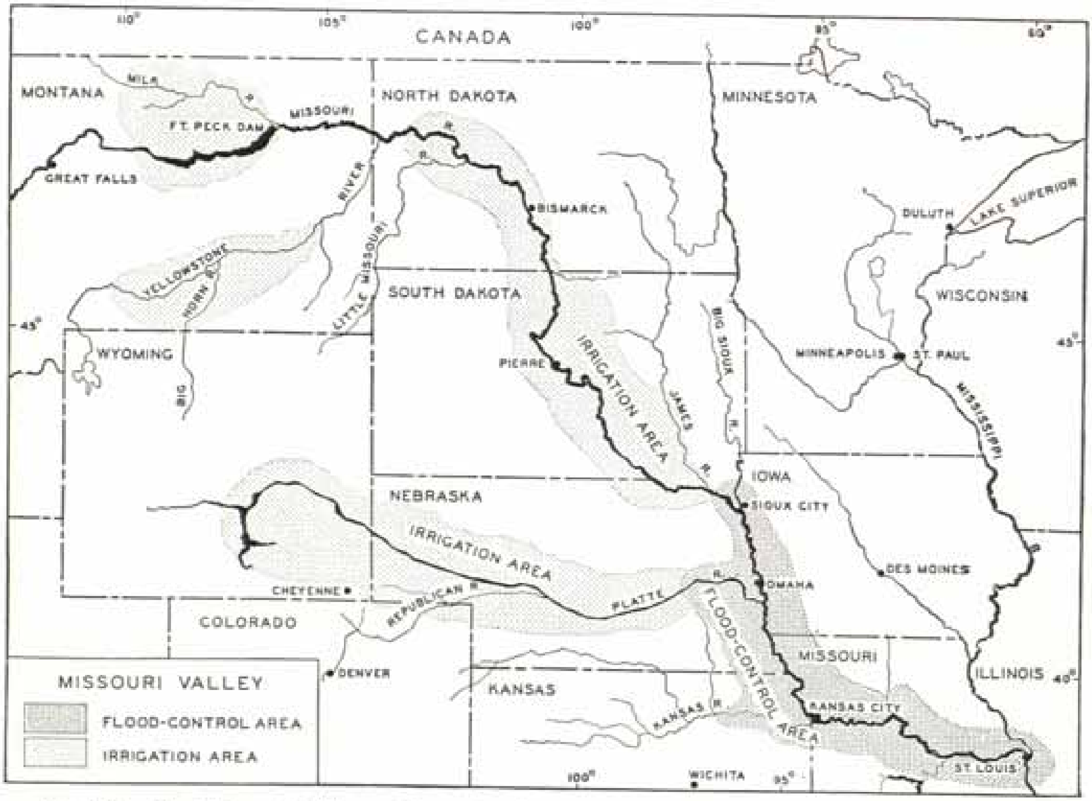


FIG. 145. The Missouri Valley and its major drainage lines, with the areas which would "profit," or be affected most by the establishment of an "Authority" comparable to TVA.

solved successfully by the local governmental units of the region.

If a Missouri Valley Authority is established, its program for improvement will have four major objectives: (1) irrigation of some 5,000,000 acres of additional land in the upper and middle stretches of the valley, where agriculture without artificial application of water is highly speculative in character; (2) improvement of the Missouri River for navigation in its lower course, where channel depth is inadequate during low-water stages of the summer months; (3) flood control in downstream areas, where regularly recurring high-water stages submerge farms and peril urban communities; and (4) power development on the swift-flowing headwaters of the main river and its principal tributaries.

The desirability of control of the flow of the Missouri, one of the world's most unruly rivers, is obvious. It would prevent much destruction of property and loss of life; it would assist in checking serious soil erosion; it would aid in guaranteeing security to farmers; it would develop a more adequate highway for moving freight by water; and it would provide an enormous amount of power, sufficient to meet all the present needs of the region, and any foreseeable in the immediate future, in both urban and rural communities.

However, it is estimated that the total cost of such control might well exceed $1,000,000,000, and this must be balanced against the possible benefits. Further, it is believed by many that this cost could not be met by the communities served, except in small part, but would need to be assessed against taxpayers elsewhere, individuals who would not benefit directly and perhaps not even indirectly from the project. Again, many object to the paternalistic aspects and the entry of government, though this aspect of the question, as with TVA, is outside the scope

of the present discussion, even though of great importance.

The Hoover Dam Project. Another governmental project, designed primarily to develop power, is the Hoover Dam project. This was begun in 1931 and completed five years later at a cost of $120,000,000. The dam, which impounds a lake 230 square miles in area and enough water to cover the state of New York to a depth of 1 foot, or a total 2-year flow of the Colorado River, is located in Black Canyon, on the Arizona-Nevada line. (See Fig. 155.)

Like the Tennessee, the Colorado River fluctuates greatly in volume, both from year to year and within the year. At extreme low-water stages, flow may not exceed 1300 cubic feet per second;

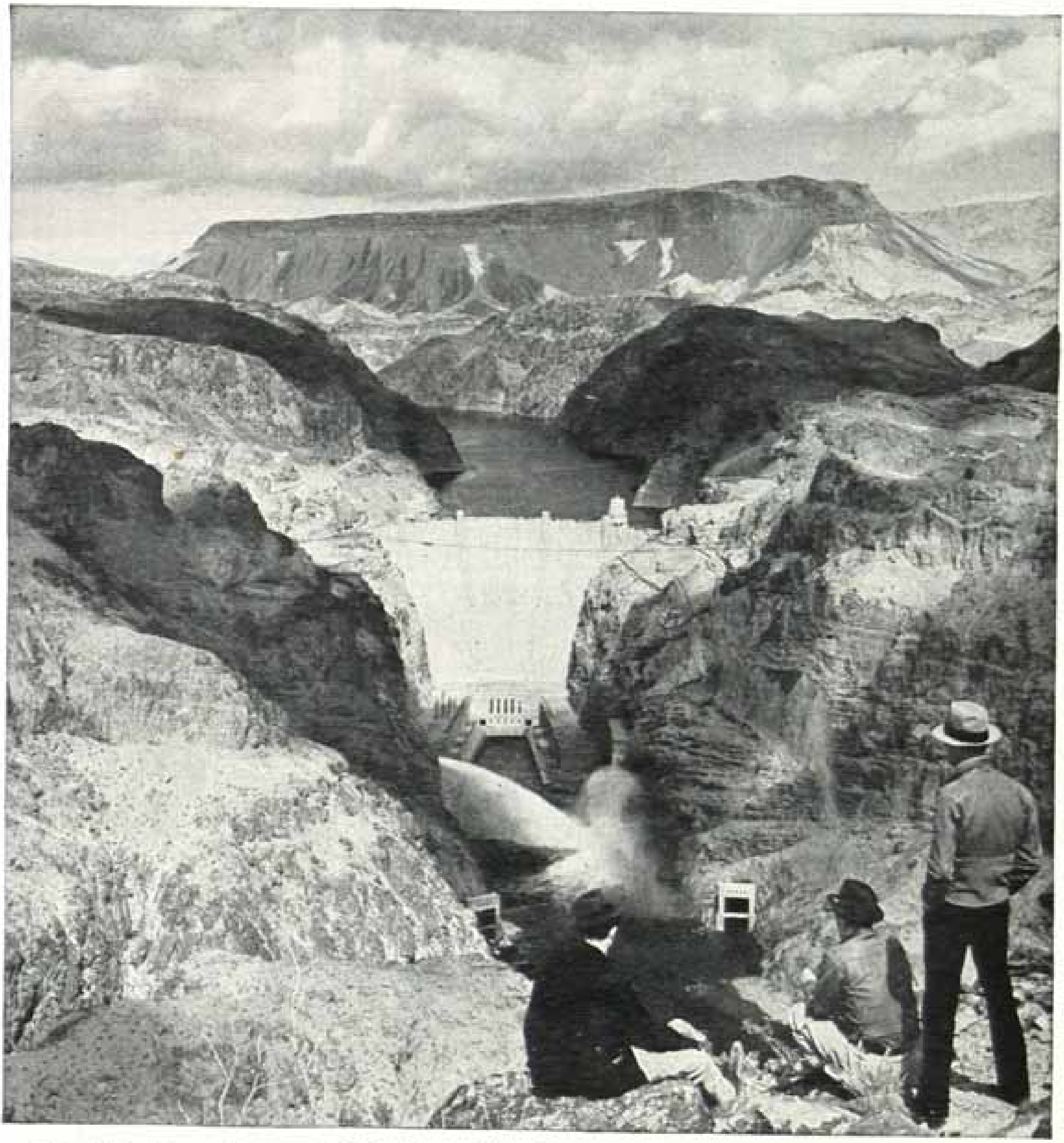


FIG. 146. Hoover Dam and Lake Mead. The dam accommodates a four-lane highway, on which cars can be seen. In August, 1939, 29,182 cars and 216 busses used this highway, bringing 108,528 tourists. (Courtesy of the U. S. Bureau of Reclamation.)

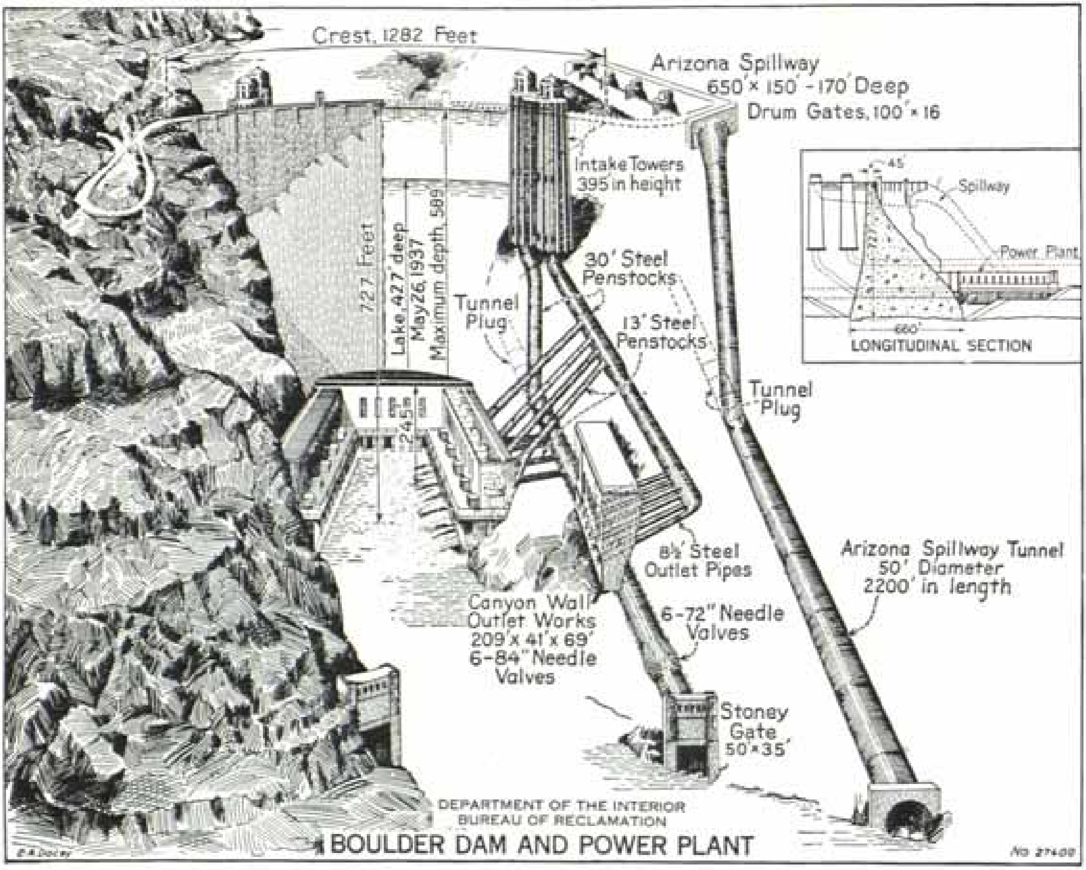


FIG. 147. The Arizona wall of the canyon has been cut away to show the intake towers, the spillway, the penstock pipes, and the outlet works. There is a similar set of diversion works on the Nevada side. The powerhouse in the bottom of the canyon is two city blocks long, and as high as a 20-story building. Dimensions on the drawing show the huge scale of the construction. Tunnels used to divert the river during construction are now plugged as shown, and in greater part used as portions of the penstock and outlet systems. (Courtesy of the U. S. Bureau of Reclamation.)

at high-water stages of record, flow has been 240,000 and there is reason to believe that it may reach 300,000 cubic feet per second. The additional fact that the Colorado River is one of the muddiest rivers in the world has caused some question as to the effective life of the reservoir, known as "Lake Mead."

The 1,835,000 H.P. available at Hoover Dam are sold as falling water, the costs of operating and maintaining the generating plant being borne by the purchasers of the power. Contracts for power were completed in 1930; generation began in September, 1936; all purchase contracts became operative June 1, 1937. The expectation is, and it is justified, that sale of power will amortize costs of construction of the dam and power plant, with interest, in 50 years, and in addition pay some revenue to Arizona and Nevada in lieu of taxes.

Coulee Dam Project. Another undertaking designed to use part of the slightly more than 9,000,000 H.P., estimated to be possible of development on the Columbia River and its tributaries, is the Coulee Dam Project, one of several designed to improve the river for navigation, development of power, and other uses. Started in 1933 with an allocation of $15,000,000 from P.W.A. funds, the total investment is expected to be $500,000,000 or more, but the project will not be completed for some time, though power production began March 22, 1941. Eventually, this project will develop 2,100,000 H.P., some-

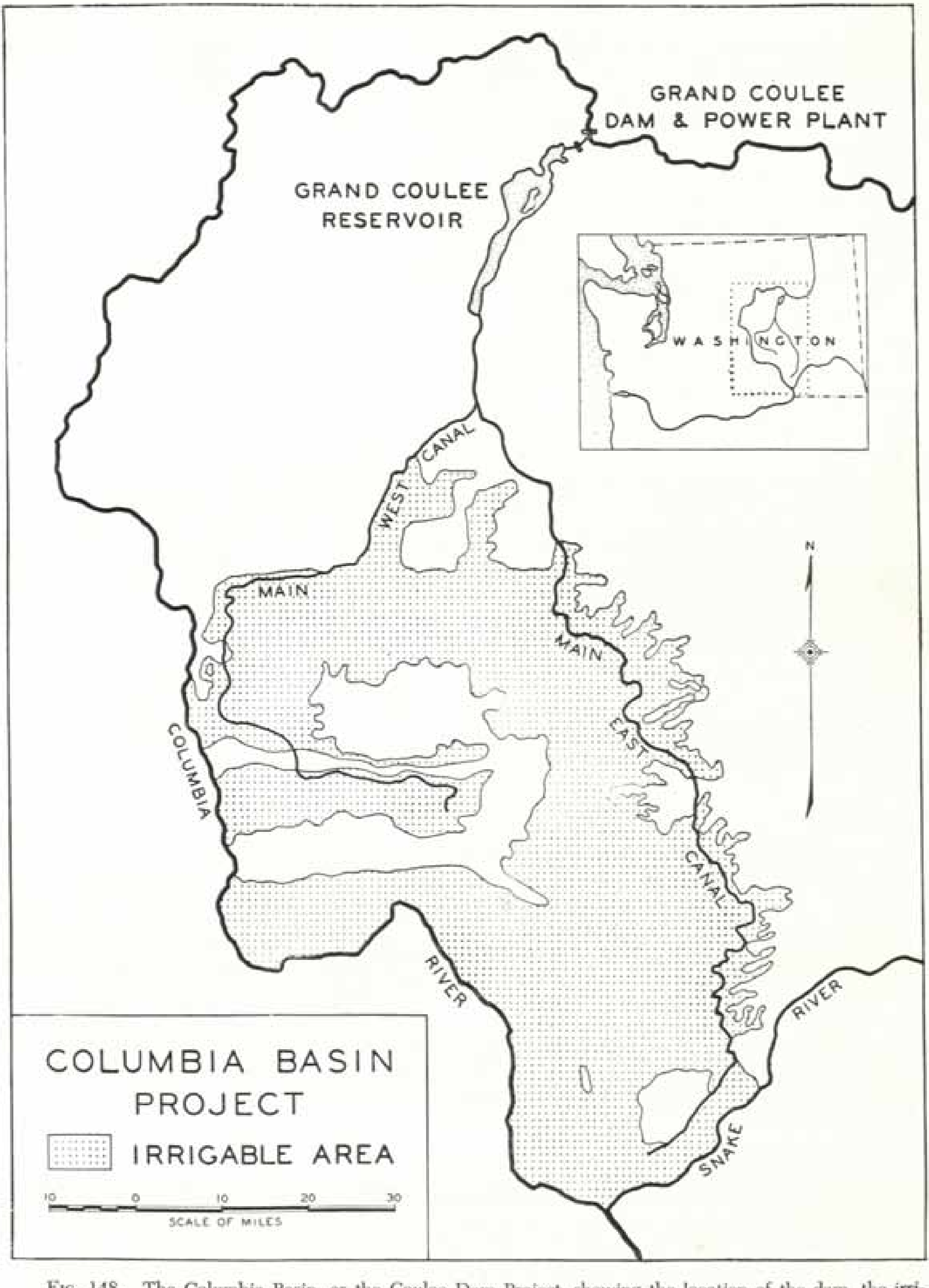


FIG. 148. The Columbia Basin, or the Coulee Dam Project, showing the location of the dam, the irrigation reservoir, and the area to be irrigated. (After the U. S. Bureau of Reclamation.)

what more than the Hoover Dam, and considerably more than the Tennessee Valley project. Completion of the undertaking now in progress will also bring 1,200,000 acres of land under irrigation in the Big Bend country, east of the Columbia and north of the Snake River. Water, elevated 200 feet by pumping from the reservoir behind and by use of power developed at the dam, will be stored in Coulee Lake, a natural depression, from which it will run by gravity to most of the area to be irrigated.

Construction of the 550-foot high Coulee Dam, which salmon cannot pass to reach upsteam spawning beds, threatened enormous loss. To prevent this, the entire run was trapped below the dam; eggs were removed from the female fish, fertilized, and transferred to nurseries. Later, the fingerlings were released in streams which discharge into the Columbia below the dam. Today, the mature fish return to these same streams to spawn, thus preventing in substantial part at least the loss threatened by man's interference with nature, in his attempt to develop power.

Government Projects. Though only a few of the more important of a relatively long list of government projects, those discussed are typical.

FIG. 149. Coulee Dam and, in the background to the upper right, the Grand Coulee, a natural depression. The powerhouse at the west end of the dam, the largest of all masonry dams, houses nine 150,000 horse-power turbines and nine generators; a similar powerhouse is planned at its east end. In the foreground is temporary Mason City; across the Columbia River is "Engineers' City" (Coulee Dam). (Courtesy of the U. S. Bureau of Reclamation.)

Some hold forth considerable promises for the future; others are of debatable desirability. In general, those which have involved careful study and consideration before commitment to actual construction show more promise than do those begun because of expediency and after only superficial investigation of their merit.

Hydroelectric Power and Man. The extent of use of power is often considered to measure the degree of development of an area. If this basis for measurement is accepted as satisfactory, then the presence of possible sources of economically developable power adds to regional potentialities from the standpoint of man. It should be realized, however, that despite this fact each stream poses a separate problem. Therefore no general statement as to the desirability of stream use for any given purpose, including development of power, is possible. In certain areas, generation of hydroelectric power has been distinctly advantageous; in others, the desirability of such generation may be open to serious question, especially where potential water power is only one of the important values of the interior waterways.

QUESTIONS AND EXERCISES

1. Why is proximity to coal a factor in determining the economic feasibility of developing power by utilizing stream flow? In what single item of power costs is saving by use of water power sometimes a possibility?
2. Why do plant and generation costs for hydroelectric power development vary so greatly? Why do they tend to rise in all areas? Why is the margin of saving possible by use of hydroelectric plants decreasing steadily?
3. What physical characteristics of streams favor their use for power development? How does each affect desirability for such use?
4. State the conditions under which a stream may be used to advantage for power development.
5. In what respects are conditions at Niagara Falls favorable for power development?
6. Discuss the distribution of potential and developed water power for the world and the United States. Why do estimates of potential water power vary so widely? Why does the relationship between developed and potential water power vary so greatly in different parts of the United States?
7. Is use of water power in this country increasing or decreasing? How rapidly? Why will future increase in the use of water probably be slower than in the past?
8. Why are multiple-purpose projects of river improvement preferable to those designed to accomplish a single objective? Of what type are the Federal projects?
9. What are the objectives of the Tennessee Valley project? Which one is most important? Why? What percentage of the operating costs is assigned to each of these objectives? Why did this assignment of costs change during the war?
10. How many installations are there in the Tennessee Valley project? Where are they located? What is the installed hydroelectric generating capacity? Is it all used? If not, why was it installed? What is the generating capacity of the steam plants? Why are they necessary?
11. State both the advantages and the handicaps for power production in the Tennessee Valley Project. What effect has dam construction in connection with power development had on stream flow? In what respects is this an advantage? Discuss the economic aspects of TVA.
12. What are the objectives of the proposed Missouri Valley project? How large is the area which would be served by this project? What states would be affected? What are the objections, if any, to this proposed control of the Missouri River?
13. Discuss the power development aspects of the Boulder Dam project. In what respects does it differ from that of the Tennessee Valley? What are the objectives of this project? What state derives the major benefits from this undertaking?
14. Locate the Coulee Dam project and discuss its power possibilities. What objectives other than power development will be secured?

SELECTED REFERENCES

Herring, W. E., and others, *Report of the Water Planning Committee of the National Resources Board*, Washington, 1934, Part III, Section II, Part XIII.

This section of the report deals with hydroelectric power in the United States.

Parkins, E. A., and Whitaker, J. R., *Our Natural Resources and Their Conservation*, John Wiley and Sons, Inc., New York, 1939, Chap. XIII.

This chapter furnishes a good discussion of water power and its conservation.

Chapter Nineteen

INLAND WATERS AND IRRIGATION

Water Requirements of Crops and Irrigation. Crops use large amounts of water. An average hill of corn grown in the Missouri Valley, for example, uses approximately 7 quarts of water each day during the month of maximum growth, and a total of about 616 quarts during the entire season. However, not all crops use the same amount of water. In general, garden products need less than fruit and field crops, and among the field crops the water requirements of corn are much greater than those of the small grains such as wheat and barley. Rice, by contrast, needs much more water than does corn. Further, the amount required for a given crop varies with the locality, which affects the rate of evaporation. Thus sugar beets grown in Alberta, Canada, need only about 75 per cent as much water as those grown in the Missouri Valley.

The amount of water required by crops is usually stated in acre-feet, 1 acre-foot being the amount necessary to cover 1 acre of ground to a depth of 1 foot. This equals 43,560 cubic feet, 325,850 gallons, 1,303,400 quarts, or 2,717,600 pounds. If the amount of water required for profitable crop production is not supplied by precipitation, or if a seasonal deficiency exists, water must be furnished artificially, or irrigation must be practiced to permit successful agricultural use of the land.

Irrigation in Humid Areas. Irrigation is practiced to some extent in practically all parts of the United States, for few areas have such abundant and well-distributed rainfall that occasional application of water is not beneficial at some time during the frost-free season. East of the Mississippi, however, irrigation is normally limited to lawns and gardens of urban centers, and to certain crops in rural areas, in view of the fact that its cost is not warranted by the returns from others. In general farming, even in areas with relatively light but normally sufficient rainfall, it is customary to select crops which can be grown profitably with the expected total and distribution of precipitation rather than to supplement the amount supplied by nature, so that production of others with greater or different water requirements may be possible.

In practice, therefore, irrigation agriculture in areas of moderate to ample rainfall is limited to production of those crops which yield high returns per acre cultivated, and to certain special crops such as rice. Under such conditions, the expense entailed by irrigation does not impose a prohibitive tax on the returns from agriculture. Thus truck gardeners and fruitgrowers of the well-watered East find it profitable to install irrigation systems, and to supply water from wells and streams when rainfall is deficient in amount for, without such application, partial or total loss of the high-yield and high-priced crops would more than offset the costs of irrigation. For a crop such as rice, which is grown under swamp conditions, or on wet, overflowed land, artificial application of water is generally necessary. For this reason, there is a considerable amount of irrigation in the rice-growing areas of Louisiana, Arkansas, and California. The same is true in eastern Asia, where rice is often the most important cereal crop. Practically all irrigation water used in growing rice is obtained from streams or other supplies of surface water, so that production is confined to areas where topographic conditions permit easy diversion of such water to the fields under cultivation.

Thus in Japan, where rice is so important as a crop that its acreage exceeds that of all other cereals combined, it is grown on the alluvial soils of the plains which border stream courses.

Since the rivers which formed these plains carry a heavy load of sediment, they have built up their beds to an extent that, though confined by embankments or levees, both natural and artificial, they flow above the general level of the bordering plains. Therefore simple diversion and gravity flow supply water to the rice fields or paddies. These are likewise the topographic conditions of the rice-growing regions of China, where rivers may flow so far above the level of the countryside that disaster and famine follow when confining levees break during flood stages.

Irrigation in Arid and Semiarid Regions. In the drier or semiarid parts of the world, where grazing generally assumes great importance, irrigation is necessary to ensure certain yields with sufficient regularity to warrant use of land for crop production. In truly arid areas, agriculture without irrigation is impossible, and even grazing is limited to a few favored localities, except as possibilities for its expansion are afforded by water supplied by wells, or from a considerable distance through man-made channels. It is probable that, in all, approximately one-third of the earth's land surface is too dry for effective cropping without irrigation.

FIG. 150. An irrigated strawberry farm in southern Michigan. Water is pumped from a small stream and distributed by an overhead system of horizontal pipes, from which the water issues through numerous small holes as an artificial rain. (See also Fig. 311.)

The early civilization of Egypt, an essentially

FIG. 151. Irrigation ditch and rice fields in Hokkaido, the northern island of Japan. Water, supplied by the melting snow of the mountains in the background, will later be used to flood the paddies or small fields, not planted as yet, for it is April and still cold in this northern island. The piles in the fields are straw from last year's crop; along the canal is material dredged from its bottom. Both will be used as fertilizer on the paddies.

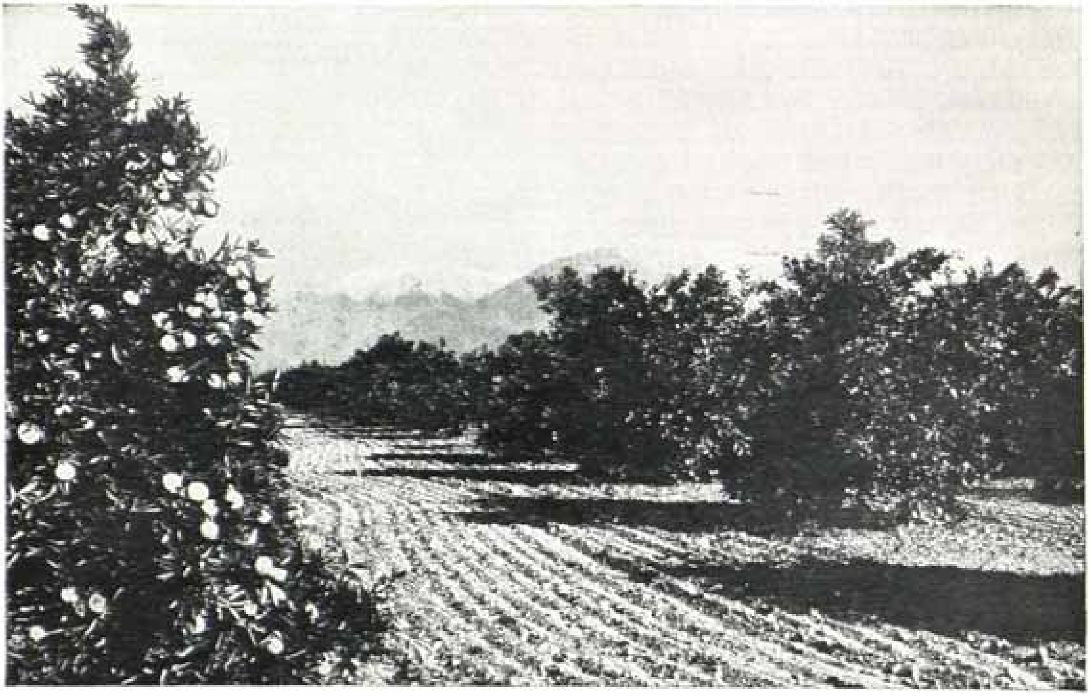


Fig. 152. A typical Los Angeles County orange grove. With a summer deficiency in the approximately 15 inches of annual precipitation, irrigation is necessary for successful horticulture in this dry subtropical climate. Note how the ground under the trees is kept cultivated, both to permit absorption of irrigation water when it is applied, and prevent loss after application. (Courtesy of the Los Angeles County Chamber of Commerce.)

rainless area, was made possible only by irrigation. Long prior to the existence of written records, man utilized natural overflow of the Nile and water elevated from the stream by crude lifts to grow crops on the flat land bordering the river. Later, he built canals and dams to extend the area capable of cultivation. Such practices made Egypt one of the early garden spots of the world though, even with such improvements, water was often unavailable when needed most. By the beginning of the present century, construction of the great dam at Aswan, which impounds 326,500 acre-feet of flood water, or enough to cover 326,500 acres to a depth of 1 foot, provided a supply sufficient to permit irrigation of 80 per cent of the cultivated area of Egypt throughout the year.

Similarly, much of the attraction of India, the first among all irrigated areas in the world, with approximately 50 per cent of all land under ditch, results from natural conditions which permit irrigation. These are afforded in part by wells and tanks in the Deccan, but more largely by the great rivers of the north, the Indus and Ganges. These rivers, fed by melting snows of the high Himalayas and the heavy monsoonal rains of their lower slopes, offer a dependable supply of water for irrigating the fertile plains of the Indo-Gangetic depression, wherever precipitation deficiency makes this necessary.

Irrigation is also important in regions with a dry subtropical climate with little summer precipitation, like the Mediterranean areas of Europe, where approximately 4,000,000 acres are under ditch: 75 per cent in Italy, the balance about equally divided between Spain and southern France. Most of the irrigated areas of the world are in the Northern Hemisphere, but a few are south of the equator: in southern Africa and South America, and in Australia. All are in the dry subtropics, or in areas with arid and semiarid types of climate.

In the United States, which ranks second only to India in acreage irrigated, Mormon settle-

ment of the Salt Lake Oasis, the present extensive occupation of the Phoenix area in Arizona, and of the Imperial Valley in southern California, would have been impossible without irrigation, since all three are very dry areas and, as in others of similar character, the limits of occupation and development are fixed by available water supply.

Areas Irrigated in the Western United States. Disregarding the relatively small acreages of the humid and subhumid eastern United States, where irrigation is practiced to a limited extent but is not necessary for the practices of general agriculture, the irrigated area of this country is confined to the 17 western states which are either all, or in part, arid or semiarid. In these states, the irrigated land totals 18,941,000, and the estimated potentially irrigable land, 51,459,000 acres, distributed as follows by drainage basins:

In considering the preceding tabulated data, it should be realized that under "total area irrigated" only the land actually irrigated is included, though an additional 6,000,000 acres with facilities for irrigation, but not used, are under ditch. This indicates only about 75 per cent utilization of present irrigation facilities and creates some doubt as to the desirability of their expansion until such time as those already in existence are also in use. In considering the data, it should likewise be kept in mind that water requirements are variable in amount, probably averaging about 2 feet, but ranging from a few inches up to as much as 5 feet or more each year. Therefore the relative desirability of irrigation in different drainage basins is not shown.

Sources of Irrigation Water. Approximately 80 per cent of the water used for irrigation in the

Drainage Basins	*Percentage of Total Irrigated Area*	*Percentage of Total Area Susceptible of Irrigation but Not Irrigated*
North Pacific Drainage Basin	19.18	19.74
South Pacific and Great Basin Drainage Basins	31.77	35.19
Colorado River Drainage Basin	13.39	14.23
Western Gulf Drainage Basin	9.43	6.93
Southwestern Mississippi Drainage Basin	3.91	3.39
Missouri Drainage Basin	22.32	20.52
Total	(18,941,000 acres) 100.00 per cent	(51,459,000 acres) 100.00 per cent

Fig. 153. Irrigation by well, Phillips County, northeastern Colorado. This well supplies 1000 gallons of water per minute to the main irrigation ditch, which runs south from the well house. (Courtesy of the U. S. Soil Conservation Service.)

United States is supplied by surface waters; about 10 per cent by underground water, or wells of various types; and about 10 per cent by a combination of the two. This indicates a considerable dependence on underground water, even more important than the percentages may suggest, since such irrigation is generally practiced on land of high value, devoted to the production of high-return fruit or other crops. Withdrawal of ground water for use in such areas frequently exceeds replenishment by rainfall or other means, which depresses ground water level and forces deepening of wells. Such exhaustion of the stored supply indicates an overexpansion and the desirability of some contraction of the irrigated acreage.

Where irrigation is by use of surface waters, the physical characteristics of the stream which furnishes the supply determine its desirability. Optimum conditions are ensured by large volume, with but slight variability of flow, and both low silt and dissolved mineral content. Large volume and constant flow guarantee an adequate supply when needed. Freedom from silt prevents clogging of reservoirs and ditches. The reservoir above Roosevelt Dam on the sediment-laden Salt River, near Phoenix, Arizona, for example, lost 6 per cent of its storage capacity between 1911 and 1935 by silting, and the smaller Horse Mesa Reservoir, a few miles downstream, was filled completely. The loss of storage capacity, even though apparently small, is very serious. An exceptionally high content of dissolved mineral matter in the water, always probable in dry areas, is never beneficial, and in some areas where much water must be applied it may be very objectionable.

Ownership of Irrigation Enterprises. Development of irrigation in the arid and semiarid West was, up to the beginning of the present century, by private enterprises: individual, communal, and corporative. The earliest, such as Mormon occupation of the alluvial fans at the foot of the Wasatch Range near Great Salt Lake, and others of the Colorado Piedmont, between 1849 and 1870, were largely communal enterprises. Some were organized around a religious belief; others were distinctly communistic; still others were sponsored by land companies, or established with the idea of social betterment. These earlier developments are among the most prosperous of our irrigation enterprises, their success resulting from good choice of location with low costs for irrigation, satisfactory management and social conditions, and intelligent selection of the right type of settlers. The general success of these induced unwarranted views as to the possibilities of irrigation and considerable unwise settlement, sponsored by both railroads and local organizations.

Subsequent to 1880, most of the irrigation enterprises like those of the Valley of California and of the Rocky Mountain area, were joint stock companies, using surface water, with stock held by users of the water. Where development of artesian water has been feasible, irrigation has likewise been by private enterprise, with each farm having one or more wells, the flow of which is frequently supplemented by use of available surface water. In all, about one-third of the total irrigated area of the United States has been developed by individuals; another third by cooperative enterprises, some large, but mostly small.

Federal Projects. With exhaustion of projects which could be developed profitably, the Federal government entered the field at the beginning of the present century, and has now brought under irrigation more than 4,000,000 acres of land at a total cost of nearly one billion dollars. Accomplishing this has involved construction of 168 storage and diversion dams, some very expensive; 18,468 miles of canals, ditches, and drains; more than 107 miles of tunnels; 13,902 bridges; and much additional miscellaneous construction. On the basis of financial returns, a considerable number of these enterprises have been failures, since settlers have not repaid the costs, thus necessitating writing off a considerable part of the investment. Whether the social benefits will offset this loss, only the future will disclose. On the basis of past experience, however, there might appear to be some difficulty in demonstrating the desirability of increasing productive acreage by continued expenditures of huge sums by the government.

Irrigation in the Imperial Valley. The Imperial Valley is the exposed bottom of the former northern extension of the present Gulf of California. Therefore it is below sea level. It originated by the cutting off of the northern portion of the Gulf by the delta of the Colorado River, and subsequent evaporation of the water, for this dry area has less than 3 inches of rainfall. The Salton Sea is the shrunken remnant of the formerly

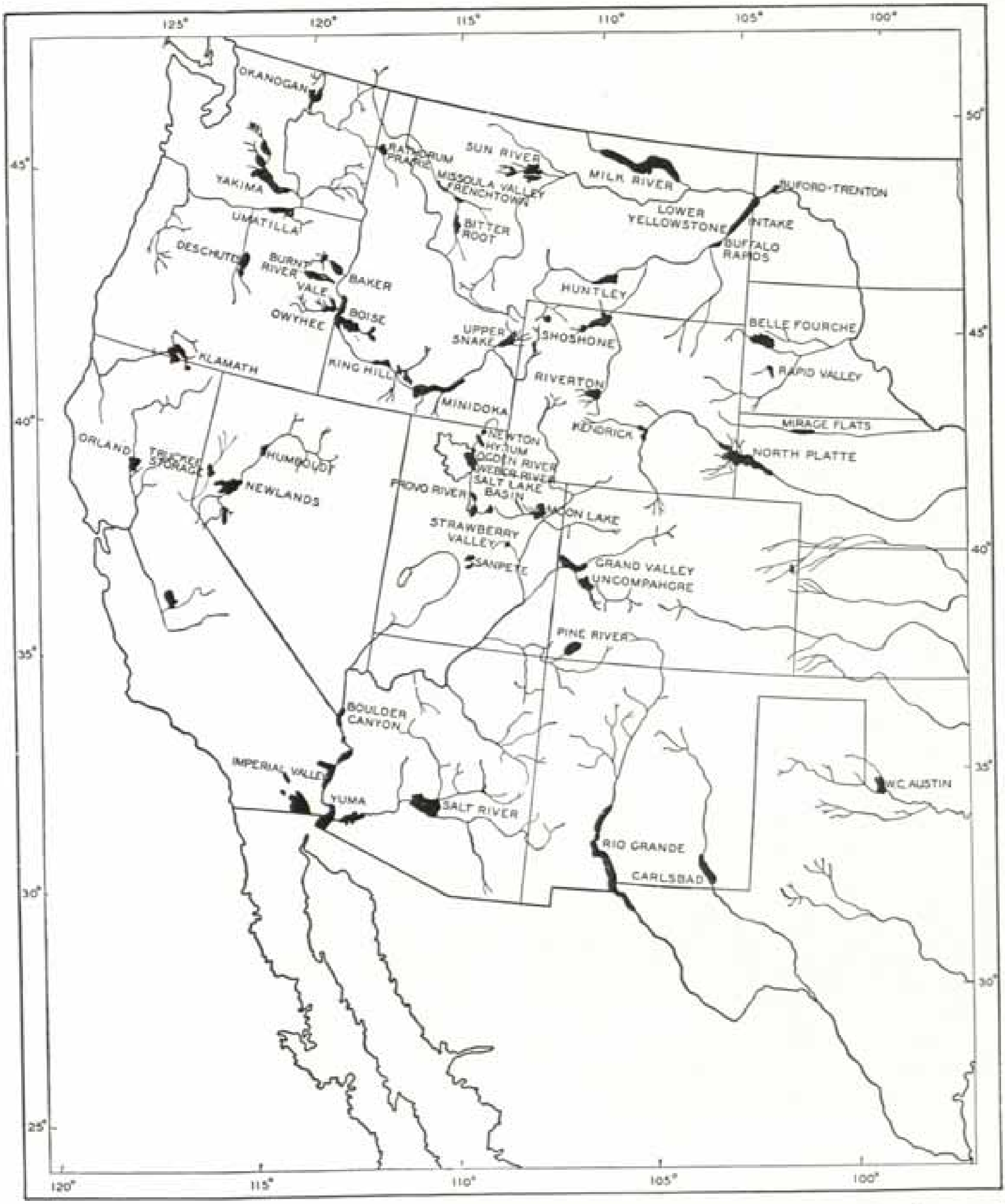


FIG. 154. Federal irrigation projects west of the 100th meridian. (After the U. S. Bureau of Reclamation.)

Fig. 155. Irrigation projects in the Colorado River Basin. (After the U. S. Bureau of Reclamation.)

more extensive body of water thus cut off. It, too, would have disappeared by now, except for seepage from present irrigation in the area.

The location and elevation of this valley attracted attention to the irrigation possibilities as early as 1853, and shortly after 1900 the California Development Company tapped the Colorado River near Yuma, diverting water through the Imperial Canal, with 50 miles of its course in Mexico. The water thus supplied by gravity flow was used to irrigate land, both in Mexico and in the United States, with most of the development in the United States. Large acreages in the Imperial Valley Irrigation District are today given over to special crops such as lettuce, melons, and other vegetable crops, in a normal year in excess of 85,000 acres. Since market demand does not permit present use of additional land for these special crops, over 200,000 acres are in hay and grain, or in less profitable use.

To obviate the disadvantages of a canal, in part in Mexico, one of the greatest of all our irrigation ditches, the "All-American Canal," has been constructed by the United States Bureau of Reclamation. This canal cost more than $38,000,000, but it is expected that users of the desilted water it supplies to more than 1,000,000 acres of land will eventually repay the costs of construction. The 80 miles of the main canal, which taps the Colorado River at Imperial Dam, 300 miles below Hoover Dam, and the 130 miles of the Coachella Valley branch, are all on this side of the International Boundary.

Construction of this new canal threatened the water supply of Mexican users who had drawn on the old Imperial Canal. This international complication has been solved by a treaty which allots in perpetuity the annual flow of the Colorado and Rio Grande rivers. This reduced Mexico's share of the Colorado River flow from the former consumption of 1,800,000 acre-feet to 1,500,000 acre-feet, with a proviso that in times

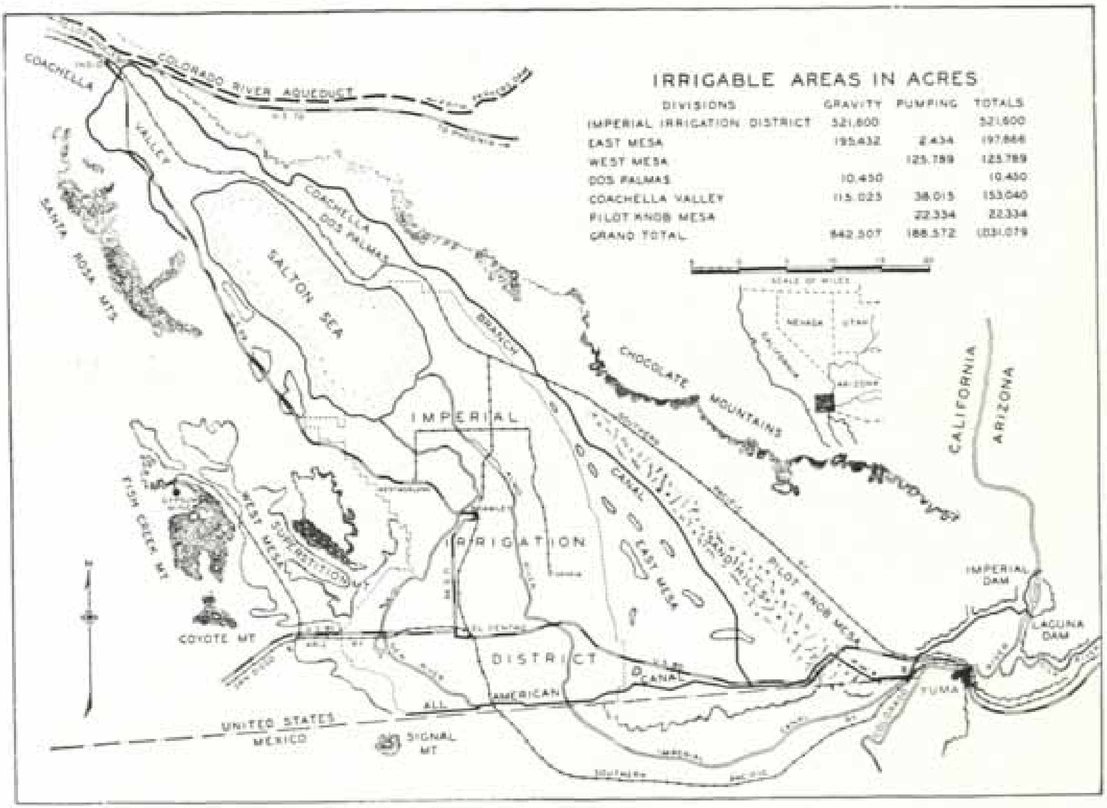


Fig. 156. The Imperial Valley of southern California, with its canals and irrigation districts. (After the U. S. Geological Survey topographic and other maps.

FIG. 157. *Top:* The Imperial Dam, with the All-American Canal in the background, curving around a mountain to the desert. Before water enters the canal, the silt is removed in the six settling basins, shown slightly to the right of center, between the reservoir and the canal. To remove the silt from the basins, each is equipped with a dozen 125-foot rotary scrapers which plow the silt into wells which discharge into the river below the dam. Therefore the water of the river below the dam is very muddy.

Bottom: A portion of the All-American Canal where it crosses the desert. In places, this 230-foot wide, 20-foot deep ditch passes through drifting dunes which must be oiled to keep the canal from filling with sand. (Courtesy of the U. S. Bureau of Reclamation.)

of surplus this amount may be increased to 1,700,000 acre-feet, but without acquiring rights to more water than the treaty provides. In times of drought both nations agree to reduce use of water on a pro rata basis. In return for this concession, which allows Mexico to use water, all supplied from the 242,000 square miles of the Colorado drainage basin in the United States, Texas will receive an additional 350,000 acre-feet of water from the Rio Grande, which it is estimated will permit irrigation of 900,000 acres, 400,000 more than in the past.

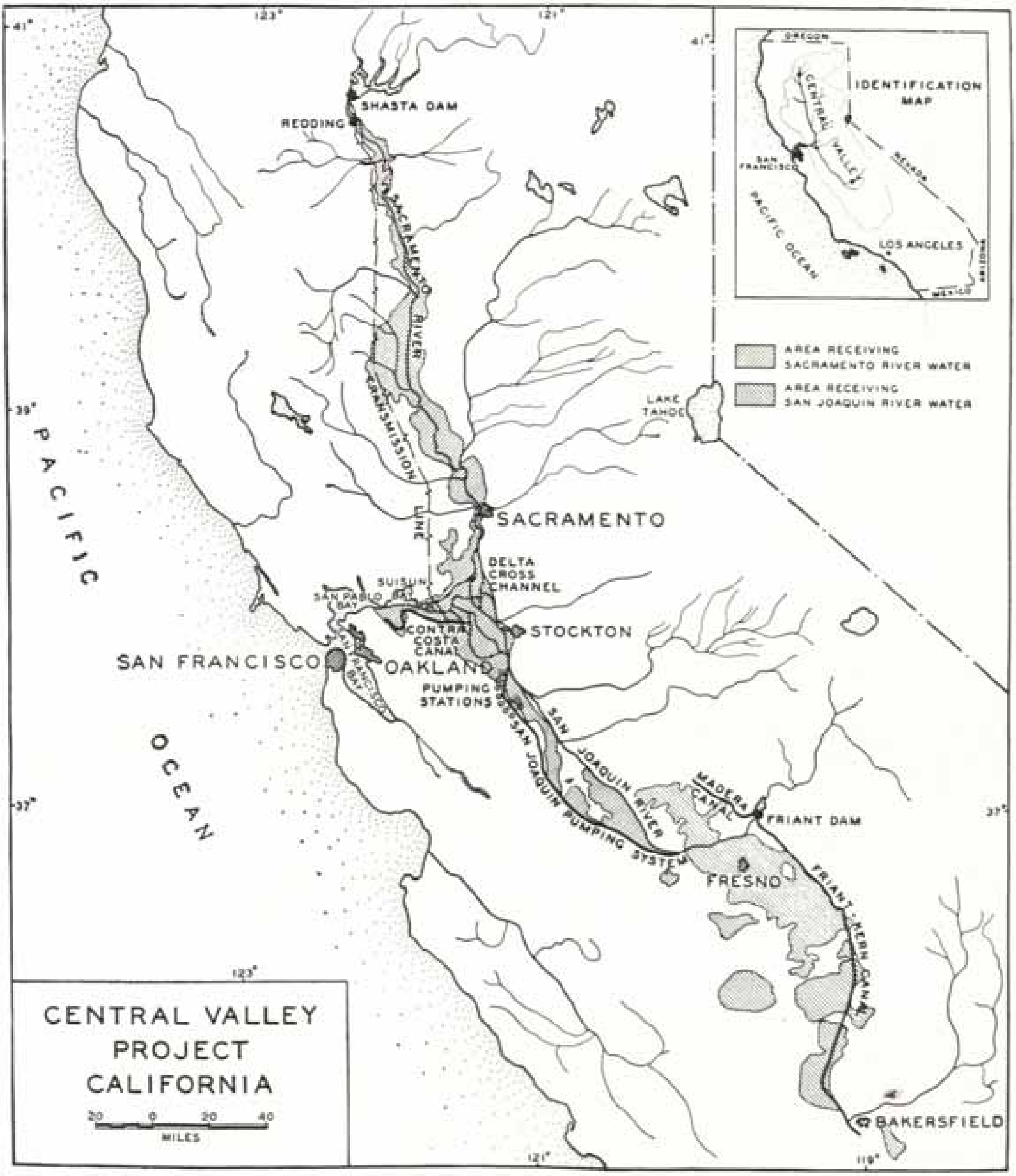


FIG. 158. The Central Valley Project, California. (After the U. S. Bureau of Reclamation.)

The Central Valley Project. The Valley of California, one of the most productive areas in the United States, is dependent on irrigation for its agricultural prosperity. Unfortunately, two-thirds of the water available is in the Sacramento; two-thirds of the production is in the San Joaquin Valley. This has resulted in such a severe drain on the water supply in the south that wells, which formerly supplied water at depths of from 10 to 20 feet, are now dry at 250 feet. This depletion of ground water has already caused abandonment of 40,000 acres, and ten times that acreage is threatened with disaster.

The Central Valley Project is an attempt to remedy this situation, both by diverting water from the Upper Sacramento to the Lower San Joaquin Valley, and by reversing the flow of the Upper San Joaquin River. These objectives are attained by two dams and the necessary canals. The waters of the Sacramento are impounded behind Shasta Dam in a 24,500-acre lake with a storage capacity of 4,500,000 acre-feet. This water is fed into the Lower San Joaquin through existing and dredged channels across the Sacramento-San Joaquin delta and, by pumping lifts, into a 100-mile canal, the San Joaquin Pumping System. The waters of the San Joaquin are stored behind Friant Dam, from which reservoir water is supplied to irrigate land to the north by the 40-mile Madera Canal and to the south by the 160-mile Friant-Kern Canal. Two additional short canals serve the delta. One, the Delta Cross Channel, is designed to cure salinity resulting from seepage of sea water into this low-lying area during low-water stages of the San Joaquin; the other, the Contra Costa Canal, furnishes water to agricultural and industrial centers south of Suisun Bay, the inland extension of San Francisco Bay.

Though designed primarily for irrigation, this, like many other governmental undertakings, is a multiple-purpose project, with flood control, dissipation of soil salinity, improvement of navigation, and obtaining water for industry as secondary objectives. In addition, it will afford power, for nearly 250,000 continuous horsepower can be developed at Shasta Dam. Of this amount, approximately 20 per cent will be used to pump water for irrigation. The balance will be marketed on the farms and in California urban centers.

Expansion of Irrigation. The earlier belief that the possibilities of irrigation were virtually boundless has today given way to a realization that the percentage of the total land surface of the 17 dry states needing irrigation and practicable to irrigate is very small, ranging from 0.22 per cent in Oklahoma to a maximum of 16.8 per cent in California, with an average of but 4.58 per cent for the entire area. Though only slightly more than one-third of this irrigable land is now under ditch, the stage has already been reached where unwarranted expansion of agriculture in some projects during a series of wet years overtaxes the supply of water to be secured by simple diversion of stream flow in dry years. If storage of water becomes necessary to ensure success in agriculture, it will make irrigation in those areas much more expensive than it has been in the past and, if made available, it will probably have to be by governmental action, since the possibilities for profit are not sufficiently great to tempt investment of private capital.

Though the earth in its natural condition, particularly in dry areas, is not ideally suited to man's use, and though artificial application of water in such areas may be beneficial, irrigation is obviously not a cure-all for the problems arising in connection with agriculture in areas of deficient rainfall, quite apart from those common to agriculture everywhere. This is in part because the application of irrigation water in itself produces the possibility of increasing soil salinity, waterlogging, undesirable change in soil texture, and other effects, discussed in some detail in Chapter IX. Thus, though man alters the limitations imposed by the natural environment by irrigation, he may, and sometimes does, impose others in their stead which offset, either partly or completely, the advantages accruing from his attempts to improve conditions by irrigation.

QUESTIONS AND EXERCISES

1. Discuss the variation in the water requirements of crops. What are the water requirements of garden as compared with field crops? Of corn as compared with wheat? Are the water requirements of a given crop constant, irrespective of where grown? Why?
2. How is the water requirement of a crop ordinarily stated? What is the value of the unit em-

ployed? State some conversions of this into other units.

3. Discuss irrigation practices in humid areas. What crops can be irrigated to advantage in such areas? Why? Why limited to these crops? Why is irrigation so important in Japan, where rainfall is ample?
4. What country leads all others in the area of land under irrigation? What country ranks second in this respect? Why is irrigation necessary in Egypt? Discuss changes in irrigation practice in Egypt.
5. Why is irrigation less important south of the equator than to its north? Where is irrigation practiced in the Southern Hemisphere?
6. How much land is irrigated in the United States? Where is it located? Why is irrigation practiced in Arkansas? What are the sources of irrigation water used in the United States? What is the relative importance of each of these sources of supply?
7. How do stream characteristics affect the desirability of a given source of surface water supply for irrigation? State those characteristics which increase desirability. Those which handicap use of a stream for irrigation.
8. How have the irrigation enterprises of the United States developed? Has this development been uniform at all periods? If not, what changes have occurred?
9. To what extent have Federal projects added to the irrigated area in the United States? Discuss the economic soundness of the Federal projects.
10. How do natural conditions favor irrigation in the Imperial Valley? How did the new All-American Canal introduce an international problem? How has this problem been solved?
11. What types of crops are grown in the Imperial Valley? Which are most profitable? Why are others grown? Why does the growing of the more profitable crops introduce a labor problem? Is expansion of acreage of these crops probable? Why?
12. How has overexpansion of agriculture affected use of the land in the San Joaquin Valley? How is it proposed to remedy the present deficiency of water supply?
13. Why is the delta of the Sacramento-San Joaquin subject to soil salinity? How is this to be cured? What crops are grown in this area?
14. What is the major objective of the Central Valley project? How is this to be accomplished? What are the secondary objectives of this project? Where will power be developed? How much? For what will it be used?
15. Discuss the probability and desirability of expansion of irrigated acreage in the United States. Why is irrigation not a cure-all in arid and semiarid areas? What undesirable effects frequently result from irrigation?

SELECTED REFERENCES

Herring, W. E., and others, *Report of the Water Planning Committee of the National Resources Board*, Washington, 1934, Part III, Section II, Part XI.

Part XI of Section II consists of a brief discussion of irrigation, its distribution, and the importance of different sources of irrigation water in the United States.

Parkins, E. A., and Whitaker, J. R., *Our Natural Resources and Their Conservation*, John Wiley and Sons, Inc., New York, 1939, Chap. VI.

Chapter VI supplies an excellent and comprehensive treatment of the utilization and conservation of our arid and semiarid lands, problems of current interest and importance, particularly in the West.

Chapter Twenty

WATER SUPPLY

Water Supply a Critical Environmental Factor. Since man cannot live without water, both the quantity and quality of the locally available supply are of great importance. This applies to both ground- and surface-water resources, which differ fundamentally only in respect to place of occurrence at a given time. Such waters find use in homes, industry, and agriculture, water rather than soil commonly being the critical factor in determining agricultural productivity. For these reasons, the conservation or effective use of ground and surface waters becomes a matter of universal concern.

Sources of Water Supply and Their Desirability. Where a local supply of surface water for domestic use is insufficient or undependable in amount, and ground water is difficult and expensive to obtain or unsatisfactory in either quantity or quality, dependence may be on stored rain water. In the Bermudas, for example, rain water furnishes the entire supply for household use. Such water, if not exposed to contamination during collection or storage, is entirely satisfactory in quality.

Ground Water as a Source of Supply. The occurrence, amount, and availability of ground water vary with climate, topography, soil, rock characteristics, and vegetal cover. Quality varies in general with quantity; where abundant, ground water is generally potable, but where limited in amount often highly mineralized. Ground water obtained from shallow wells is generally better, except for the possibility of pollution, than that from deeper wells in the bedrock, in the waters of which a high degree of mineralization is not uncommon. In all, approximately 50 per cent of the people of this country and millions of animals use water from wells, or ground water, at least in part. In addition, it is used in thousands of industrial plants and for air conditioning. In much of the United States, ground water is even more important than surface water as a source of supply for both home and industry.

Ground water often suffers from the handicap of hardness, which seldom affects potability, but generally does limit desirability for many domestic and a great variety of industrial uses. Hardness, a measure of dissolved mineral content, is ordinarily determined by the quantity of the carbonates and sulphates of lime and magnesium present, both distinctly objectionable. These substances accumulate as an incrustation on the insides of teakettles, as boiler scale in industrial use, and in the wicks of humidifying devices in which hard water is used, so that they become stiff and ineffective in promoting evaporation. It is not surprising that water containing such minerals is called "hard water" for, when used, it is hard to make a lather with soap; it is hard on both the hands and fabrics; it is hard on pipes and plumbing; and hard in many other ways, even on the pocketbook.

Tolerable hardness varies with use. With a mineral content of 0-60 parts per million, or less than 0.497 of a pound per 1000 gallons, water does not require softening for domestic use nor is its value for most industrial purposes impaired materially. If hardness is between 60-120 parts per million, or the dissolved mineral content does not exceed 0.994 of a pound per 1000 gallons, softening is both economically possible and generally desirable. If higher, costs tend to become prohibitive for industrial uses where soft water is necessary. Undesirable mineral constituents, other than lime and magnesium compounds, are those of iron and manganese, which deposit with alteration in physical or chemical conditions in

the water. It is this iron content which causes the reddish stains, so difficult to remove, where water drips from a faucet or stands in some container. In many industries, complete removal of such compounds is necessary before the water can be used.

The quantity, quality, and source of ground-water supply vary in different portions of the United States. In the glacial drift of much of the Lake States, ground water from shallow wells furnishes adequate amounts of potable, though sometimes hard, drinking water. In western South Dakota, by contrast, the water in the underlying sandstone is both too far below the surface and excessively hard. Even in the eastern part of the state, where these supplies have been tapped, their high degree of mineralization makes them poorly suited for most uses. The ground water in the till plain or glacial deposits to the east of Glacial Lake Agassiz, and in the clays of the former lake bed, the present Red River Valley, is likewise very hard. The high sulphate waters, dilute solutions of Epsom and Glaubers salts, obtained from wells in these deposits are, in fact, often so highly mineralized that they are unfit for use by man or for watering livestock.

Surface Water as a Source of Supply. The quality of surface water varies with runoff. When this is small in amount, the dissolved mineral content tends to be relatively high and, if organic contamination is present, it becomes concentrated. During periods of abundant runoff, by contrast, the percentage of mineral matter lessens and dilution decreases that of organic contamination. At extreme low-water stages, sea water sometimes invades the lower courses of rivers, causing losses to both domestic and industrial consumers of water. In the Philadelphia area of the Lower Delaware River, the total loss from this cause for the 4-year period ending in 1933 is estimated to have been $6,500,000. Similarly, the leveed land below the confluence of the Sacramento and San Joaquin rivers in California is affected adversely when salt water invades the stream channels and seeps into adjacent areas under cultivation. One of the objectives of the Central Valley project is to eliminate this possibility of soil salinity. (See Chap. XIX.)

The quality of both surface and ground waters is affected by the amount of precipitation. During the great drought of 1934 rivers fell so low that, not only was navigation impeded and power development curtailed, but disaster likewise befell many irrigated areas, where stored water proved insufficient in amount to provide for the needs of agriculture. In 1934, not only were surface waters lowered and the yields of corn decreased 40 per cent, but ground-water level was also depressed from 10 to as much as 30 feet over large areas. This caused many wells to go dry. (See Fig. 159.) The dry fall of 1939 had a similar, though less pronounced effect. In arid regions, where dependence is solely on irrigation, similar droughts have depopulated extensive areas during past periods of history, often being credited as the cause of important migrations of population.

Droughts and Their Effects. Great droughts are even more disastrous than great floods since the latter are local, of limited effect, and their damage can be prevented. Droughts can neither be prevented nor can their occurrence be predicted at present. It is not even possible to state with any certainty that they are more frequent and widespread, or of greater severity than in the past. Even prevention of the damage they bring cannot be ensured; all that is possible is alleviation of the distress they produce.

Human Activities and Water Supply. Human activities have affected the water resource of the United States adversely through: (1) tillage and drainage, (2) wastage from flowing and pumped wells, and (3) contamination of the supply. The first two of these have tended to reduce the quantity of the effective supply; the last to make the available water less desirable for use.

Contamination yearly becomes more serious with increase of settlement and urbanization, despite present attempts at prevention. In all, there are four major sources of this pollution: (1) erosion, which causes turbidity or muddiness, not tolerable in water for either domestic or industrial use; (2) industrial wastes, which unfit water for all uses; (3) mine drainage, largely acid and very objectionable because it causes corrosion and scale; and (4) sewage and city wastes other than those resulting from industry.

Objectionable erosion is preventable. For many liquid industrial wastes, however, the only effective place of disposal is a body of surface water or a sewer. In highly industrialized areas, this has led to great pollution of surface waters, which increases yearly with development of new industrial processes with large water requirements,

resulting in growing volumes of liquid wastes which cannot be utilized and must find disposal. Pollution by sewage likewise becomes more serious yearly, with increasing consumption of water for sanitary purposes, even more rapid than increase of population.

In determining the effects of pollution, it is necessary to take into account both the ability of stream alkalinity to neutralize acidic contaminants and that of dissolved oxygen to destroy organic wastes indirectly. To accomplish this latter, the dissolved oxygen content of the water must not fall below 50 per cent of saturation, in order to support the bacteria which reduce the organic matter. The limit of safe pollution, then, is determined by the chemical character of the wastes and the volume of oxygen content of the dilution water, measured by bacterial flora.

The increasing seriousness of organic contamination is shown by the findings of the Tri-State Commission of New York, New Jersey, and Connecticut, covering an area with a population of 10,880,000. These showed that, by 1931, the oxygen content of the Lower East River, and of the Harlem River as well, was 0 per cent, indicating an alarming concentration of sewage. Such contamination has an adverse effect on practically all uses of rivers; in the New York area it even interferes with recreational use of the beaches. In the Chicago district, pollution of the waters of the lower, dead end of Lake Michigan finally forced formulation of a comprehensive sewage-disposal program.

The Ohio River Pollution Survey, recently conducted by the United States Public Health Service, disclosed a similarly alarming case of stream pollution. This study covered a highly industrialized area of 204,000 square miles with a population of more than 19,000,000. Of this number, 50 per cent were served by sewers, with 34 per cent of the sewage treated before discharge into streams. In addition, industries produced wastes equivalent to those of an additional population of 10,000,000. In this area, also, the acid waters draining from mines, both active and abandoned, daily added free and combined sulfuric acid, equivalent to at least 4900 tons of 100 per cent acid, with an additional 168 tons supplied each day by the "pickle liquors," or spent acid of the steel mills. Though in general detrimental, such acid waters coagulate and precipitate organic matter as a sludge. This accumulates on the stream bottom, thus preventing offensive odors. During freshets, however, this material is carried downstream to tax the water-treatment facilities of other communities.

It has long been a common practice to divert city wastes into rivers and lakes, which likewise serve as sources of supply for much of our water, in addition to being of great value for many other uses. For many years, also, this was not particularly objectionable, for dilution and natural purification occurred to an extent that no damage resulted. Even today, the total volume of waste, 6000 million gallons daily, is less than 0.5 per cent of the average daily stream flow in the United States and could be disposed of without difficulty, except for its uneven distribution, which is a cause for serious concern.

Water Supply in Underdeveloped Areas. Among primitive populations, dependence is on surface waters. Therefore, where rivers and springs are lacking, even though ground-water supply may be adequate, occupation is handicapped or even impossible. Such conditions may occur in limited areas underlain by limestones, where practically all drainage is underground and only the larger rivers, few in number and far apart, flow at the surface. They are likewise the rule in semiarid and desert regions.

In the United States, the drinking of water without much if any question concerning its source is a common practice, though sometimes unwise; but in many parts of the world such a procedure would invite almost certain sickness and possible death. In most of China, and likewise in all but a few of the larger Japanese cities, the drinking water is generally open to suspicion, for, with the intensive agricultural practices and heavy fertilization of land in production, surface waters, and the ground water in the shallow open wells which furnish the supply for domestic use in rural areas, are badly polluted by organic material. This is probably why tea rather than water is used so extensively, for the necessary boiling makes it safe to drink, and the addition of tea possibly improves the taste. Even in many parts of rural Europe, raw water may properly be suspected of being too badly polluted to be used safely for drinking without previous boiling.

Water Supply in Rural United States: Household Supply. The water supply of rural areas in the United States is variable in both character

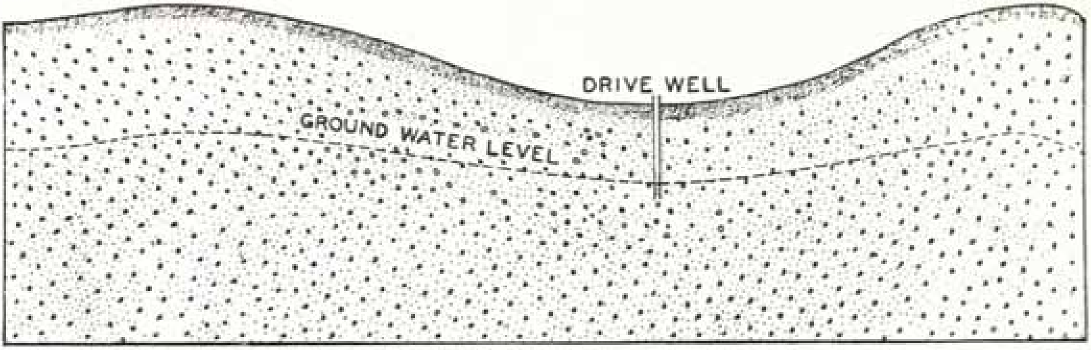


FIG. 159. Drive well in glacial drift.

and source. Sometimes the water is soft; sometimes it is hard, but it is generally sufficient in quantity in the humid East and Northeast, and, if free from organic contamination, safe to drink. The principal sources of supply for such water are driven, dug, and drilled wells; cisterns for holding rain water; and, occasionally, in the less developed areas, springs.

In areas where the mantle of glacial drift is thick, the loose material deposited by the ice serves as a reservoir holding large quantities of water, with the water table, or the ground-water level, often only a few feet below the surface. Where the drift is not excessively stony, it is often possible to obtain a supply of water by driving a pipe a few feet into the ground until it taps the water-bearing layer. Such "drive wells" generally afford an abundant and excellent supply of water; cold, clear, and, if free from contamination, entirely satisfactory, for excessively hard water is unusual in shallow wells. If the drift is too stony, it may be necessary to dig the well or, if the water is too far below the surface, to reach it by drilling. All such wells, particularly if shallow, are open to suspicion as sources of supply of water for domestic use if located near potential sources of contamination.

Throughout many parts of the South, the mantle rock, or the surface layer of loose material, is thin, and springs are lacking or variable in flow. Where this is true, rain water from cisterns affords the common supply for household use. Often, however, care is not exercised in either collection or storage of such water. Many of the cisterns are uncovered or, if covered and equipped with pumps, covers are not tight. Further, cisterns often go dry during protracted periods without precipitation during the summer months, so that a water shortage, difficult to remedy easily, frequently occurs.

Springs, the favored source of water of the early pioneers, are still used to supply drinking water in some less well-developed regions, not only in the South, but in the North and Northwest as well. Many of these furnish relatively small amounts of water but, occasionally, discharge is considerable with appearance at the surface of underground drainage in a limestone area. At Silver Springs, Florida, for example, the flow is 115,000 gallons per minute. Where population is sparse and only chance contamination possible, springs often afford a satisfactory supply of water for domestic use.

FIG. 160. A cistern in northern Graves County, western Kentucky, showing the conductor pipe from the roof and the bucket for drawing water. Since the cistern is open, there is danger of contamination of the water it holds.

FIG. 161. A sinkhole in the limestone country of Montgomery County, central Kentucky. Water stands in the depression because drainage was blocked when the roof of the underground cavern collapsed.

Water Supply in Rural United States: Farm Supply. Where springs and surface streams of uniform flow occur, they often serve to furnish water for the farm animals. Sometimes this supply may be either supplemented or displaced by ground water, pumped by hand, wind, electricity, or gas engine, and stored against a time of need.

Where surface streams and springs are uncommon, as in unglaciated areas underlain by limestone, it is frequently possible to tap an underground drainage line and secure what is locally known as a "spring," though it is somewhat different in character than one resulting from seepage. In such unglaciated limestone areas, also, collapse of the roofs of underground caverns often creates surface depressions, or "sink holes," in which water collects if drainage is blocked. These then supply water for livestock. Where springs and streams are lacking, or unavailable as sources of water supply, and soils are clay, excavation of a hole in the barnyard, with puddling and ramming of its bottom, creates a watertight basin which serves to hold rain water for the use of farm animals.

Public Water Supply. Public water supplies are obtained from both surface waters and artesian wells, but 75 per cent of the population of the United States served by public water systems depend on surface waters. If only the larger cities are considered, the percentage supplied by surface waters rises even higher, for most of our major population centers secure their municipal water supply from rivers or lakes. Thus the ten largest cities, with a combined population of 19,796,373 in 1940, all depend on surface waters. The same is true for practically all others with populations in excess of 300,000, and for many more of smaller size. The water for such systems may either be pumped from rivers or lakes, or it may be secured by diversion of the flow of streams or, occasionally, of large springs into storage basins, from which it is distributed, either with or without pumping, to the consumers.

To be satisfactory, water supplies should be ample in amount, and this is commonly the case except in dry areas. However, the volume required by large cities commonly exceeds the amount available nearby, and thus more distant supplies must be tapped. Boston, for example, secures water from sources 25 to 100 miles away; San Francisco draws upon the Sierras, 170 miles from the consuming area; and Los Angeles, satisfying its needs until recently from Owens Valley, 240 miles distant, now secures additional water by pumping from the Colorado River through a recently completed 392-mile aqueduct. Cities located on the Great Lakes, by contrast, are peculiarly fortunate in having a virtually unlimited and generally satisfactory water supply at their doors.

Under certain favoring conditions, it is possible to obtain an adequate amount of clear and pure,

though often hard, water from artesian wells. This is true in many areas covered by glacial drift; the Atlantic and Gulf Coastal Plain; and the Great Plains. In these areas, such wells are common sources of supply, 65 per cent of the smaller towns and rural communities, which need relatively small amounts of water, being dependent on them. In these areas, however, excessive pumping has in some cases depleted the supply, and contamination by sewage and, in Florida and Long Island, by salt water has occurred. In deserts, such wells, either flowing or pumped, may alone make human occupation a possibility.

In all public water systems, freedom from contamination of the supply is necessary. To ensure this generally involves protection of the watershed or catchment area from which the water is secured, and it may also necessitate sand filtration to remove suspended material, and chlorination to destroy bacterial growth, since typhoid and other intestinal diseases may be contracted by drinking water polluted by organic material.

Ownership of Public Water Systems and Consumption of Water. The first public water system in this country was that of Boston, constructed in 1652. Even as late as 1800 but one such system was operated by the public; the other 15 were private enterprises. Today, however, about 80,000,000 people in the United States are served by approximately 7100 public water systems. These use over 1,000,000,000 cubic feet of water each day, the average per capita daily consumption being about 127 gallons. In the larger cities it is greater, averaging about 140 gallons per capita per day in those of over 100,000 population, though there is also great variation from city to city, irrespective of size. At one extreme, Fall River, Massachusetts, with a population of 115,274, has a daily average consumption of 45 gallons per capita; at the other, Tacoma, Washington, with a population of 106,514, one of 430 gallons. In general, consumption tends to increase everywhere with more common installation of modern plumbing systems and greater use of water for air conditioning, industrial, and sanitary purposes. In many cities, there is much regrettable waste of water, particularly where a flat rate is charged; when the supply is metered, consumption decreases and waste is lessened.

Examples of Cities with Various Sources of Supply. Ann Arbor, Michigan, a city with a population of about 30,000, like many others of its size, depends upon shallow artesian wells, in this instance in glacial drift, for its public water supply. The water thus obtained is clear, cold, and safe to drink, but very hard, as well as having a high iron content, objectionable for domestic use because it stains plumbing fixtures. It is so hard that for many years it was a common practice to have two sets of plumbing, one to carry city water, the other to furnish cistern water to all parts of the thouse where a supply of soft water was desirable. This necessity was finally eliminated by construction of a water-softening plant in 1938.

Though the smaller urban centers commonly depend upon wells, this is not always true, Iowa City, Iowa, for example, with a population of approximately 15,000, pumping its water from the muddy Iowa River, which flows through the

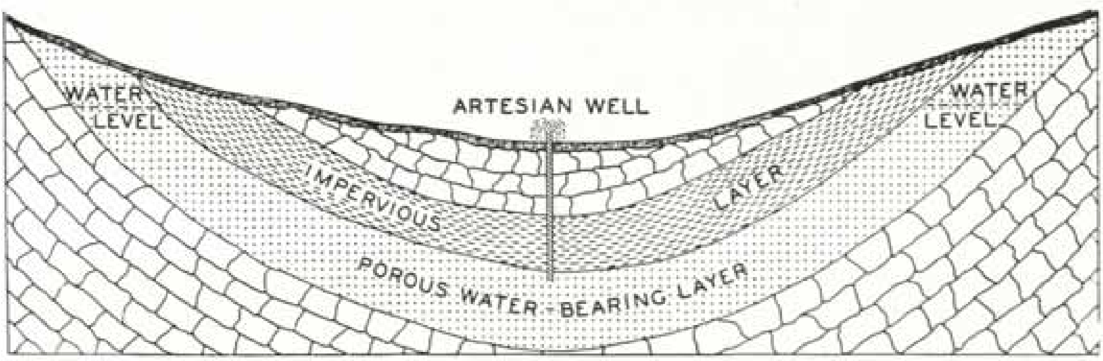


FIG. 162. Artesian wells are possible where structural conditions permit accumulation of water under a "head" in a porous layer, as shown above. Under such conditions, a well may be obtained by tapping the water-bearing layer. If the supply is partially exhausted by drawing on it so heavily that water level in the water-bearing layer falls below the top of the well, pumping becomes necessary.

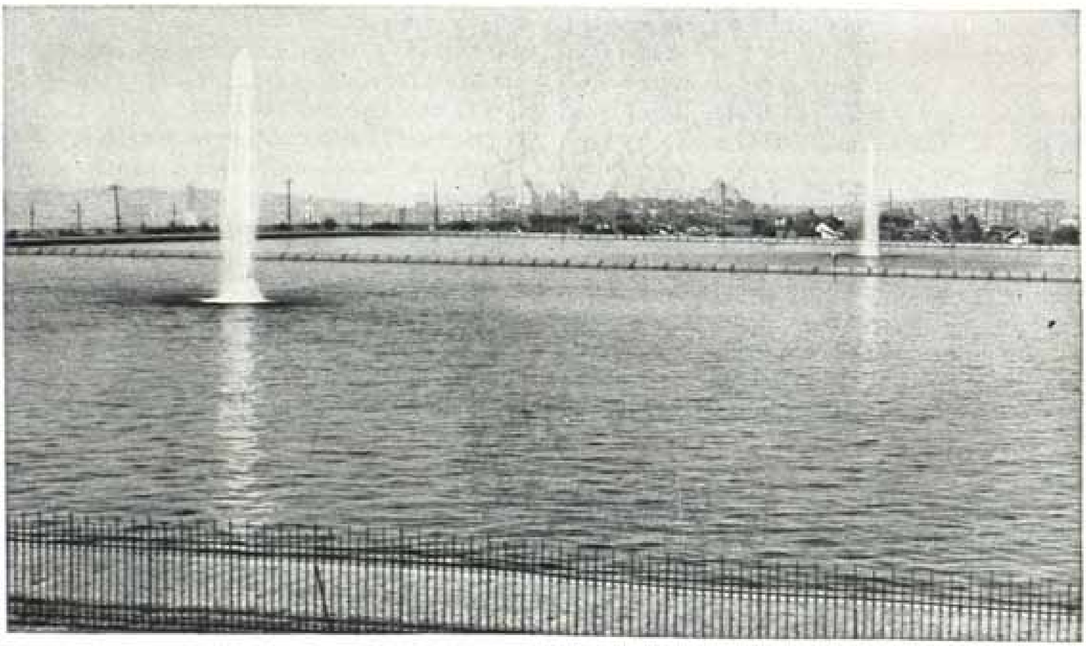


FIG. 163. *Top:* The source of supply of water for Boulder, Colorado. The 11,223 inhabitants of Boulder, like those of Seattle, draw upon a mountain stream for their water. This stream, rising in the Arapahoe Glacier in the Front Range of the Rocky Mountains, furnishes clear, cold, soft water in ample amount by gravity flow. (Courtesy of R. H. Brown.)

Bottom: The twin reservoirs on Beacon Hill, with downtown Seattle and the Sound in the distance to the west. These reservoirs have an elevation of 316 feet at overflow, and a capacity of 110,000,000 gallons. (Courtesy of the City of Seattle Water Department.)

city. After filtration and chlorination, the water is safe to drink though objectionable in odor and not particularly palatable.

Lexington, Kentucky, meets the needs of its population of about 45,000 persons by drawing upon sinkhole lakes outside the corporate limits for its water, pumping from these sources to the users. In normal years, the supply is adequate, but always subject to the danger of contamination. In dry years, the quantity of stored water may be so small that the amount is insufficient, and pollution, both inorganic and organic, may increase objectionably.

Seattle, Washington, a city of approximately half a million inhabitants at the present time, diverts a stream with a protected watershed in the Cascades for its use. Water flows by gravity into six settling basins or reservoirs, where it is desilted. From these, it is delivered to all parts of the city, largely by gravity flow. The water secured in this manner is clear, cold, and soft, its mineral content being so low, 23.93 parts per million, that it is commonly used in storage batteries. This supply is adequate in volume, and excellent for all uses.

Duluth, Minnesota, supplies its population of slightly more than 100,000 with water from Lake Superior, at the west end of which the city is located. The lake furnishes an ideal, near-by supply for the municipality, the water being sufficiently soft to be suitable for practically all uses, for the mineral content is only 54 parts per million. The pumping plant, located at the eastern margin of the city, draws water from the lake at a sufficient distance from possible sources of contamination so that little treatment is ordinarily necessary to ensure safety of the supply.

Los Angeles, California, located on the Los Angeles River, for many years depended mainly on that river for its water. Between 1900 and 1910, however, increase of population from 102,479 to 319,198 necessitated supplementing this earlier supply by drawing upon the Owens River, 240 miles distant. At first, the drain on the second source was slight, but when population passed the half million mark by 1920 the greater demand led to conflict between irrigation interests in the Owens Valley and the city, finally settled by purchase of 80 per cent of the irrigated land. Today, the present population of some 3,000,000 in the metropolitan area forces the city and its suburbs to turn to the Colorado River to secure additional water. To accomplish this, water is diverted at Parker Dam, 155 miles below Hoover Dam, through an aqueduct 392 miles in length with 92 miles of tunnels, financed by a bond issue of $220,000,000. This will satisfy needs for some time to come, insofar as quantity is concerned, but the water secured is very hard, containing 523 parts per million of dissolved mineral matter; even harder and less suitable for many uses than the early supply from the Los Angeles River, with its 378 parts per million, or 3.1 pounds per 1000 gallons.

New York City depends on impounded stream flow for its public water supply. The present sources yield a total of 1,200,000,000 gallons of water per day. Of this amount, the old Croton system furnishes 336,000,000; the recent Catskill system, 600,000,000; the balance comes from several other smaller sources. Present consumption is about 850,000,000 gallons per day, well below the amount of the present available supply, except during a dry period such as the fall of 1939. If city growth continues, however, more water will be necessary within a few years. To meet this anticipated demand, new reservoirs are planned for construction at the headwaters of the Delaware River. These will ensure an adequate supply for some time to come. Including the cost of these new works, the total expenditure involved will total nearly $800,000,000. Such an enormous investment indicates the importance of a satisfactory system to furnish water necessary for varied urban uses: domestic consumption, industrial purposes, cooling and air conditioning, and for fighting fires. Without an adequate supply, or with the supply cut off, a large urban center would be crippled even more quickly and effectively than by a food shortage. Present conditions in our large cities are a far cry from those which confront the savage who seldom, if ever, except in arid areas, is troubled by the possibility of a shortage of water.

Industrial Water Supply. All manufacturing plants require a water supply, which may be small if it is needed only for the personal use of employees and for cleaning, but again it may amount to several million gallons a day in a textile dyeing plant. Requirements as to the quality of the water likewise vary greatly. When used for cooling, quality may be immaterial; but when in a manufacturing process involving a chemical reaction, it is of fundamental importance. In the

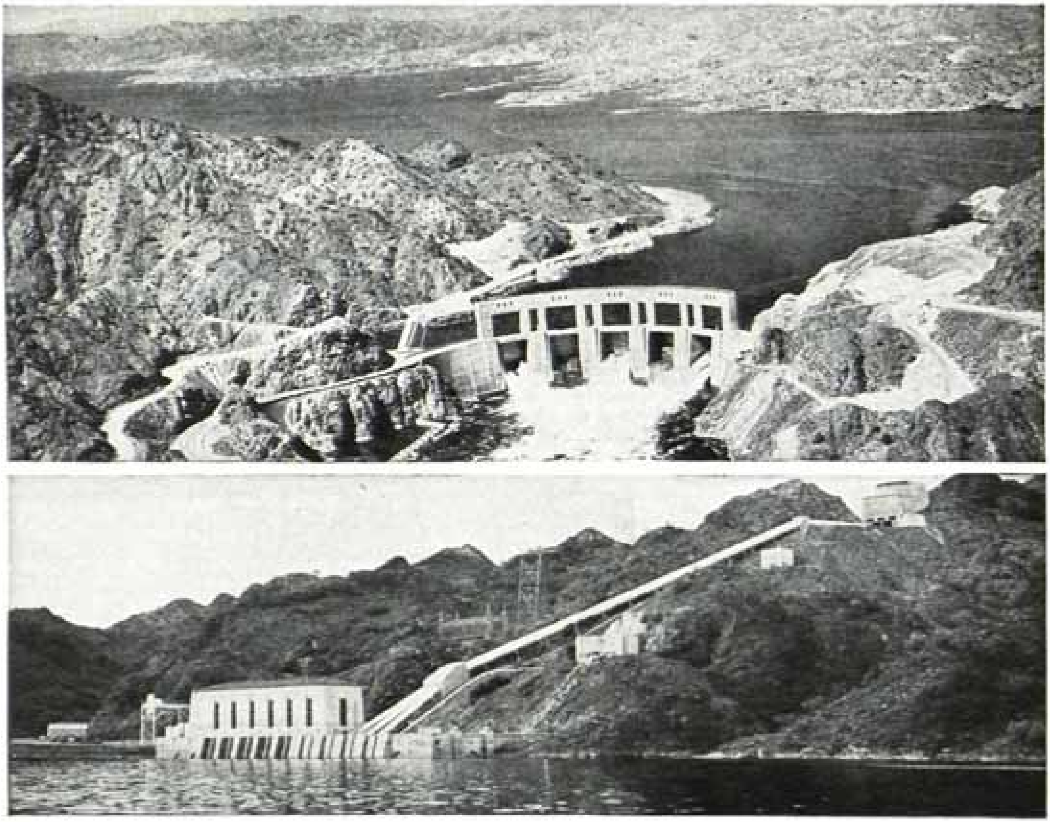


FIG. 164. *Top:* Parker Dam, on the Colorado River. This dam impounds a water supply for Los Angeles. (Courtesy of the U. S. Bureau of Reclamation.)

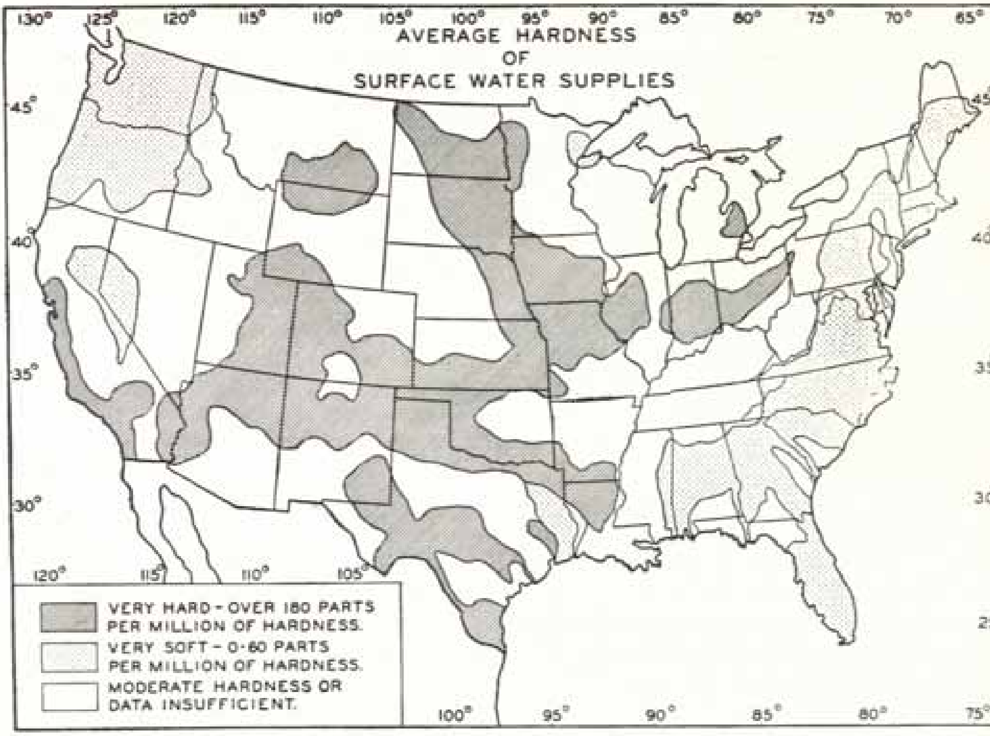
Bottom: Intake pumping plant, one of five for the Colorado River Aqueduct. Water is taken from 2 miles above Parker Dam by this plant and lifted 291 feet into the first of 39 tunnels on the aqueduct.

manufacture of chemicals, for example, the water must be so pure that it may even be necessary to use distilled water. Thus the quantity and quality of the available water supply are factors affecting the location of industrial development.

Impurities and Their Effect on Use. Practically all natural waters, either surface or underground, are weak solutions of limestone, essentially the carbonates of calcium and magnesium; some sulphates, where gypsum is present, or where the water supply is contaminated by mine or certain industrial wastes; and other minerals in lesser amounts. Of these minor impurities, one which is very detrimental in certain industrial processes is iron.

Hardness resulting from calcium and magnesium salts causes scale in steam boilers and must be removed completely for the most satisfactory results in washing and dyeing textiles, and in general laundry work. It is likewise harmful in many other industrial processes. Corrosive waters, resulting from contamination by mine wastes, are totally unfit for use in iron and steel pipes and boilers. Many waters, mildly corrosive because of dissolved oxygen and carbon dioxide, are inactive when cold but, when heated, cause rusting, clogging, and even perforation of pipes. Surface waters rarely contain iron in objectionable quantity, but ground waters often contain so much that, when oxidized on exposure to air, the red sediment formed unfits such waters for industrial use. Turbidity resulting from sediment in suspension is detrimental as it contributes to boiler scale and is objectionable in many manufacturing processes such as the preparation of food products.

Location and Expansion of Industry. The earliest industrial activities of the United States



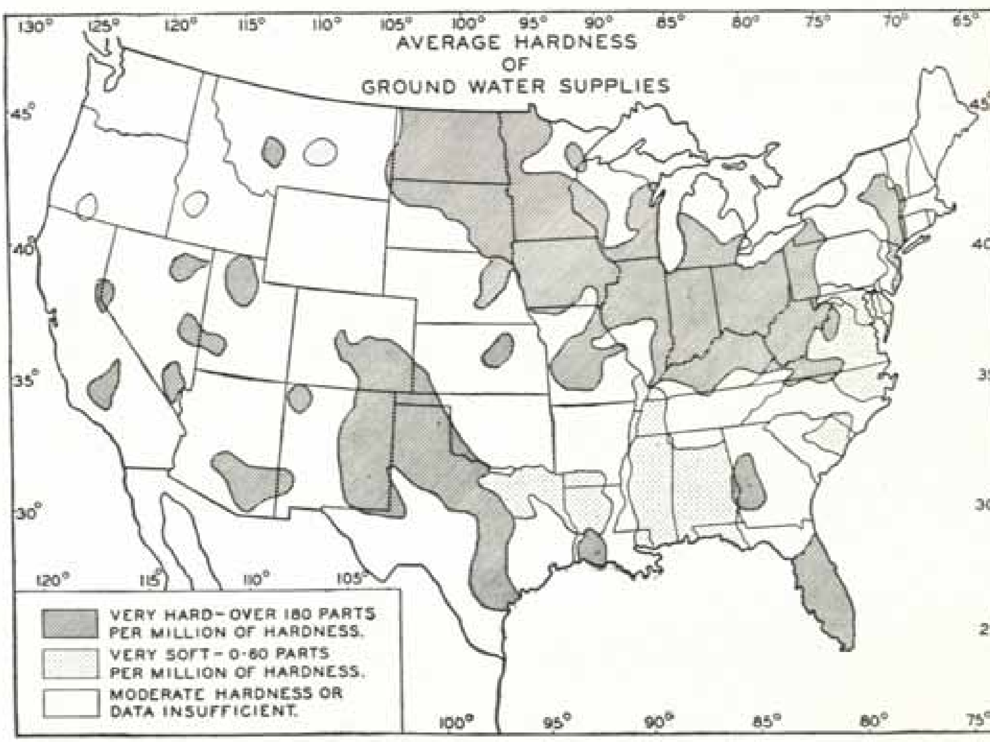


FIG. 165. Average hardness of surface and ground water supplies in the United States. (After the National Resources Board.)

were confined to areas with excellent natural water supplies. With growth and movement of population, and improved methods of purification of water, though industrial development not feasible a few decades ago is now possible in areas with hard water, types of industry which have need for large quantities of high-quality water still tend to locate where the natural water supply is ample in amount and of satisfactory quality. The reason for this is that cost of treatment, varying from 2 to 20 cents per 1000 gallons, dependent on the character of the water, size of plant, and treatment employed, may be a considerable item if the quantity of water used is large.

Growth of industries, such as the manufacture of wool, silk, cotton, knit goods, paper and wood pulp, leather, distilled liquors, chemicals, druggists' preparations, and others of similar character, during the past 50 years has been confined almost exclusively to states where the water supply is soft or only slightly hard. Industrial expansion in other areas has been of those types of industry in which water requirements are not so rigid. This is a condition which may be expected to persist.

Water Supply and Man. Water supply is as essential as the land, for it alone makes man's use of the land possible. Nevertheless, like the land which affords support, water is frequently used wastefully, even in dry areas, where necessity might appear to dictate its conservation as the price of existence. It should be realized that water, even though supplied free, is variable in distribution, limited in amount, and all afforded by precipitation, even that which is stored underground. The uneven distribution results from dissimilar precipitation, in association with variable evaporation, runoff, and subsurface conditions, which affect the amount of both surface and ground water available in any area at a given time.

Where the supplies are abundant and the quality of the water is satisfactory, regional opportunity is improved; where quantity is small and quality poor, areal potentialities are decreased. It is therefore highly desirable to conserve the resource. With this objective in mind, accelerated erosion should be checked, pollution prevented, and waste eliminated, for only by intelligent use of water supply can man preserve the natural balance which makes for maximum opportunity. It is well to remember that man is not essential to the earth, though the earth is to man, and that he should, therefore, regulate his activities correspondingly.

QUESTIONS AND EXERCISES

1. What is the fundamental difference between surface and ground waters? Why is water supply a critical factor in determining the possibility of human occupation of an area?
2. What is the source of the domestic water supply of the Bermudas? Why? Where are these islands located and who owns them?
3. What is the relation between the quantity and quality of ground water supply? Why is water from shallow wells commonly less mineralized than that from deep wells?
4. What is meant by "hard water"? Why is hardness objectionable for many domestic uses? Name those for which it is objectionable.
5. What determines "tolerable hardness"? What are the objectionable dissolved minerals in hard water? What degree of hardness unfits water for most industrial uses?
6. Name some areas in which mineralization unfits the water supply for most uses.
7. With what factor does hardness of surface water vary? How do low-water stages of surface waters sometimes affect the quality of ground water in Florida and California?
8. How did the great drought of 1934 affect ground-water supply? How do such great droughts compare in seriousness with severe floods? Why?
9. How and in what way have human activities affected the water resources of the United States?
10. What are the principal sources of pollution of our water supply? How may such pollution be prevented?
11. Why is pollution of our water supply increasing? What is the present condition in the New York and Chicago areas? In the industrialized Ohio Valley region?
12. Why did lack of a surface-water supply prevent occupation of an area by primitive man? Why are water supplies of the Orient commonly unsatisfactory for domestic use?
13. In what part of the United States are cisterns a common source of supply of water for domestic

use? Why are such supplies commonly contaminated?

14. State the common sources of water used for watering livestock on farms in the United States? In what part of the country is each of these used? Which ones are used in your home area?
15. What percentage of the population of the United States depends on surface-water supplies for its public water systems? Is this source of supply more important in large or small urban centers? Why?
16. What is the average daily per capita consumption of water in our cities? Is consumption increasing or decreasing? Why?
17. Discuss the water-supply problems of Los Angeles and New York City.
18. What qualities must a water supply possess to make it satisfactory for industrial use?
19. Why are hardness and iron objectionable in a water supply for industrial use? What other objectionable impurities may interfere with such use?
20. How is location of industry affected by quality of water supply? What has been the history of expansion of those types of industry requiring large amounts of soft water in the manufacturing process? Why? Name several industries in which need for a large volume of soft water is so important as to affect their location.

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This reference offers an extended discussion of the topics treated in this chapter of your text, and in the references which follow.

Collins, W. D., "Relation between Quality of Water and Industrial Development in the United States," *Water Supply Paper 559*, U. S. Geological Survey, Washington, 1926.

This bulletin, which is illustrated by many maps, discusses the location of industry as affected by water supply in considerable detail.

Powell, S. T., and others, *Report of the Water Planning Committee of the National Resources Board*, Washington, 1934, Part III, Section II, Parts III, IV, VI, VIII, IX.

These sections of the report deal with ground and surface waters, their quantity, quality, pollution, and use as public water supplies.

Parkins, E. A., and Whitaker, J. R., *Our Natural Resources and Their Conservation*, John Wiley and Sons, Inc., New York, 1939, Chap. XII.

This chapter affords an excellent discussion of the problems of public water supply for domestic and industrial use.

Chapter Twenty-One

MISCELLANEOUS USES OF INLAND WATERS AND PROBLEMS ASSOCIATED WITH USE OF RIVERS AND LAKES

Miscellaneous Uses of Rivers and Lakes. In addition to the various uses of rivers and lakes which have been considered previously, our inland waters present opportunity for recreational, subsistence, and commercial fishing. Under certain conditions, they may also serve as the location for homes of "floating populations" and, where winters are long and cold, they may furnish a source of ice supply and make certain winter sports possible. Last, but not least, they frequently afford the basis for an important resort business.

Fishing. Recreational fishing, with the value of the food supply secured of secondary importance, is common in most parts of the United States. In vacation areas in Michigan, Wisconsin, Minnesota, and elsewhere, this attraction draws thousands to rivers and lakes each year, income from license fees being an important source of revenue which goes far toward paying for the necessary restocking of depleted waters. In limited portions of the United States, but to a much greater extent in the densely populated countries of eastern Asia, fishing on a subsistence basis, or to acquire a food supply for home consumption but not for sale, is frequently a part-time occupation, returns from which supplement income from the prevailingly small farms. Again, fishing on interior waterways may afford a full-time occupation, either on great rivers like the Mississippi, or on large lakes such as Lake Superior. This aspect of fishing will be considered in much greater detail in a later chapter.

Homes for "Floating Populations." In the United States there are many "houseboaters" who live in floating homes on our rivers and other waterways throughout the year, particularly on the Mississippi and its larger tributaries. In some cases, houseboats remained moored in one place for many years; in others, they are shifted from place to place with the seasons, or as the whims of their occupants dictate. In south and southeast China, where level land is limited in amount and population is almost incredibly dense, thousands of people occupy similar floating homes from birth to death, often being dependent for their livelihood as well upon the waters which afford a location for their habitations. This overflow of population from the land to the waterways of the Canton area is one of the most striking aspects of man's occupation of southeastern China.

Ice Supply. In parts of the country where winters are long and sufficiently cold so that ice of considerable thickness forms on all lakes and many rivers, lakes afford a common source of ice supply for smaller communities and rural areas where artificial ice is not available. Natural ice also affords recreational opportunity in these same areas, even in the larger cities of northeastern United States, where outdoor artificial rinks on playgrounds supplement skating afforded by lakes and other bodies of water. Similarly, the canals of the Netherlands swarm with skaters during the few weeks of the winter months when ice closes them for use in navigation.

Recreational Use. The streams and lakes of the United States often afford boating, bathing, and other recreational possibilities, though their value for these uses is greater in areas of relatively recent glaciation, where lakes are more numerous, the waters of both rivers and lakes are clear, and shores are less marshy than in other parts of

FIG. 166. One of the Amethyst Lakes, Tonquin Valley, Jasper National Park, about 10 miles west of Jasper, at the foot of a towering wall of peaks known as "The Ramparts." Jasper National Park, with its area of 4200 square miles, is the largest of the Canadian National playgrounds and easily accessible by rail. Each year, the attraction of mountain peaks, canyons, lakes, waterfalls, and wild life lures tourists and sportsmen in increasing numbers. (Courtesy of the Canadian National Railways.)

Fig. 167. Use of the shallow, muddy Iowa River for bathing, near Iowa City, Iowa. Such a river finds use for this purpose only where better facilities are lacking.

the country. Nevertheless, even where rivers are shallow, and often muddy as well, if better facilities for recreation are lacking, they find use, as may be seen from some of the accompanying illustrations. Likewise, wherever irregularities in stream beds cause waterfalls, as at Niagara and

elsewhere, scenic beauty attracts many visitors. Of recent years, also, construction of storage reservoirs, such as those of the Tennessee Valley and the one known as the "Lake of the Ozarks," has served to supplement the recreational opportunity afforded by nature.

In New England, the Lake States, and in many areas on the Pacific coast where natural conditions are favorable, the streams and lakes draw thousands of tourists, and recreation becomes an important business. In Michigan, it is estimated to contribute in excess of $500,000,000 each year, with $274,000,000 of this total from outside the state. Similarly, the recreation business in Wisconsin and Minnesota, the latter popularly known as the "Land of Ten Thousand Lakes," brings in comparably large sums. In some parts of these states, in fact, it is actually the most important single source of revenue.

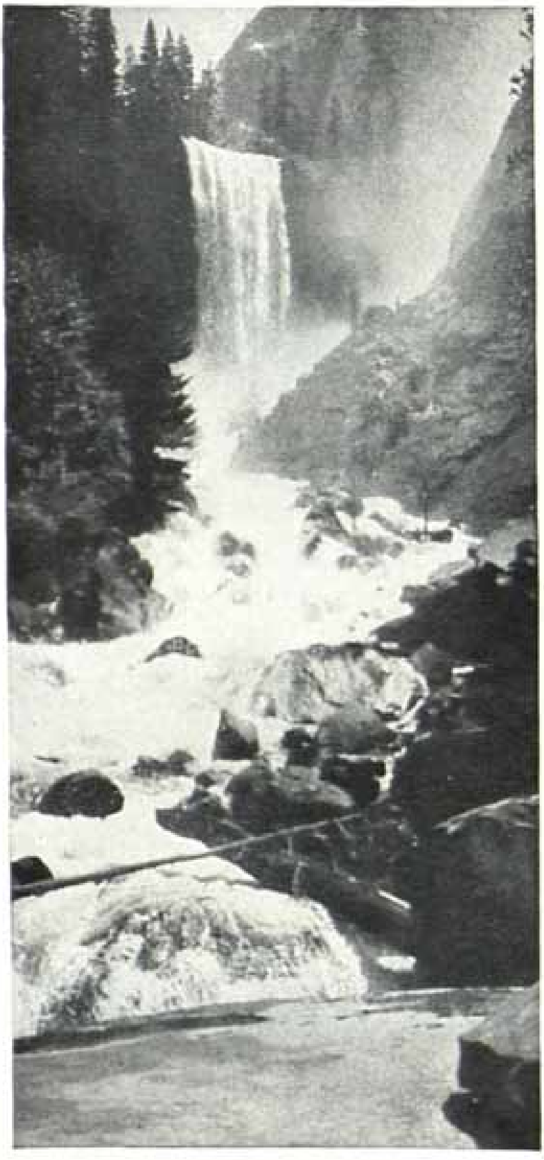

Fig. 168. Vernal Falls, at the head of the Yosemite Valley, Yosemite National Park, California. (Courtesy of the U. S. Department of the Interior.)

Part of this income is derived from cabin camps which cater to tourists who wish to prepare their own meals; part from lodges and resort hotels which supply both food and sleeping accommodations; and part is contributed by summer residents who own or rent cottages. In Michigan alone it is estimated that the number of such cottages exceeds 20,000. In Oakland County, near Detroit, there are reputed to be 400 lakes, many of which, because of their accessibility, are so built up with summer and all-year homes that they are actually the centers of villages, with most of the conveniences of smaller population centers. Somewhat similar conditions exist around much of Lake Minnetonka, west of Minneapolis, Minnesota. In these two cases, the lakes are so close to large urban centers that it is possible, in these days of good roads and automobiles, for those who live at them to work in the cities, yet spend nights and week ends at the lakes. This, essentially a development of the past 30 years, has worked a revolution in the ways of life of many who work in the cities.

In many of the cutover regions of the Lake States, cottages and resorts carry a large share, or even the major portion, of the tax burden. Not only do they represent one of the most stable forms of investment in these areas, but their summer occupants furnish a potential or actual outlet for the limited agricultural production and supplemental employment to the permanent population. They alone, directly and indirectly, enable support of the necessary community services, including schools, in many such areas of limited opportunity.

Thus in some areas the recreational asset is so important that it overshadows all others, or at least it bulks so large that it influences all other economic activities. This is true not only in the summer resort regions of the North, but likewise

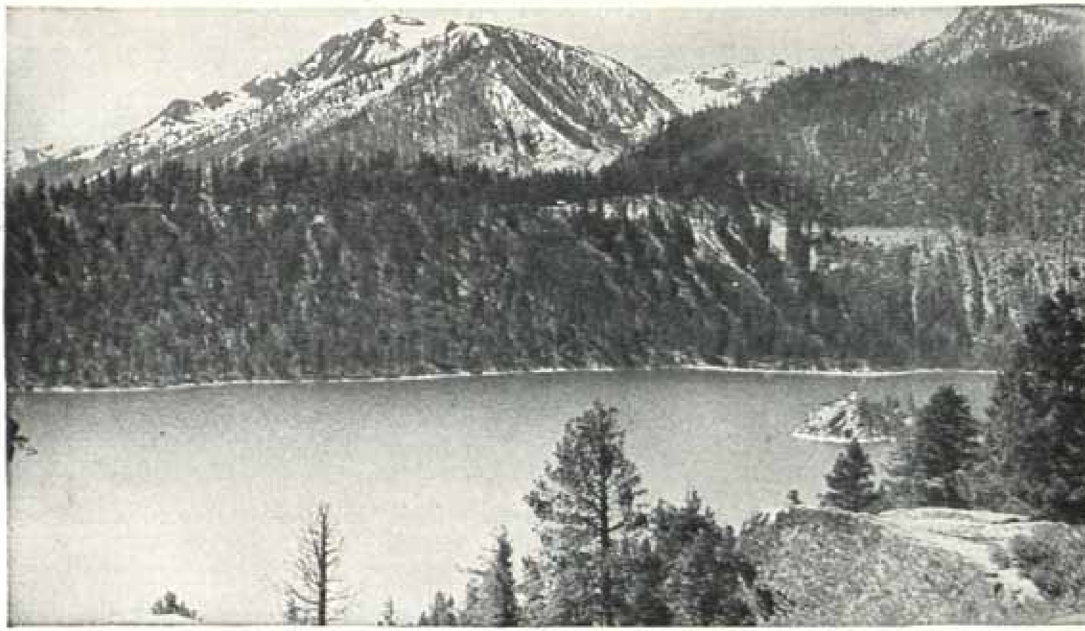

Fig. 169. *Top:* Emerald Bay and Wizard Island, Lake Tahoe, California, with the snow-covered Sierras in the background, in mid-June.
Bottom: A portion of the road which encircles Lake Tahoe.

FIG. 170. A cabin camp on the rocky Baptism River near Finland, Lake County, in the Arrowhead Country of northeastern Minnesota.

in the winter resort areas of Florida, the Gulf Coast, and parts of California. It is therefore desirable that steps be taken to conserve the natural opportunities afforded by lakes and streams and to preserve the scenic beauty where such assets serve as the basis for the recreation business, if its permanence is to be assured. It is also desirable, wherever practicable, to supplement the attraction afforded by nature by construction of reservoirs or artificial lakes in areas where natural lakes are few in number or lacking. To preserve present advantages, defacement of the landscape should be prevented, streams should be protected from pollution, unwise drainage should be avoided, and the public should be guaranteed access to natural beauty spots by keeping at least some of them in public ownership in state and national parks and forests.

Integration of River Improvement. It probably will have been noted that the same physical characteristics which affect the value of a river for one use likewise affect its desirability for several others, in varying but important degrees. Thus volume and variability of volume are not only important in determining whether a river can be employed to advantage for navigation, but also whether its use for power development, irrigation, or for some other purpose is econom-

FIG. 171. A typical summer cottage on one of the small lakes of southern Michigan, easily accessible by good roads from both Detroit and Chicago.

ically feasible. In similar fashion, gradient, silt content, extent of interruption by ice, and other characteristics are all of more or less importance in determining the value of any given stream for several uses.

In view of this fact, when a river is improved for navigation the improvement affects the desirability of that same river for other uses. For example, when dams are constructed to increase navigability, the regulation of stream flow which results decreases flood danger, increases opportunity for power development, and even improves the river for recreational use. In the Kentucky River, for example, where dams constructed to improve the river for carrying freight deepened the water over the bathing beaches, a secondary benefit resulted, though one not contemplated by the sponsors of the river improvement. (See Fig. 173.)

Because of this interrelationship of uses, it is preferable to solve the problems of river use as a group rather than singly. Instead of improving a river for navigation only, for example, it is better to improve it for all uses to which it can be put to advantage. After a decision has been reached with respect to all desirable improvements for a given river, and the amount of money which can be spent with profit for each, if the objectives desired can be attained by expenditure of the total of these sums, the river should be improved. If not, the project should be abandoned. With such a procedure, results would be more satisfactory than those obtained by piecemeal attack: first, improvement for navigation; then for flood control; and, still later, for other purposes. A practice such as suggested would not only enable intelligent decision as to whether benefits to be derived would be commensurate with costs involved, but would likewise prevent unnecessary duplication of effort and unwise conflicting operations, with accompanying waste of both effort and money.

An example of river improvement carried out in this manner is afforded by the Hoover Dam project. In this improvement of the Colorado River, the objectives were fourfold: (1) generation of power; (2) irrigation of additional land in the Imperial Valley; (3) control of Colorado River floods; and (4) supply of water for domestic and industrial use in Los Angeles and adjacent areas. Other possibilities, such as improvement for navigation, were not considered, for location and physical characteristics of the Colorado River eliminated them from the list of practicable objectives.

FIG. 172. The High Falls of the Pigeon River, in an area of great historical interest on the International Boundary between the United States and Canada. The other rivers of the Arrowhead Country of northeastern Minnesota flow through similarly beautiful rocky gorges and have comparable falls, for when they leave the Superior Upland, they drop several hundred feet to lake level within a short distance.

Before any construction was begun, the critical physical characteristics of the Colorado River such as volume and variability of volume, silt content, degree of mineralization of the water, and location of suitable dam sites were investigated, and data on all these points were assembled. With this information available, it was possible to estimate probable costs and to determine whether these were warranted by the benefits to be secured by improvement. Then,

FIG. 173. The bathing beach at Boonesboro, Kentucky, on Labor Day. Before construction of the dams designed to improve the Kentucky River for navigation, the water was too shallow for use in bathing during the summer months.

and only then, was construction begun. Such a procedure is one which should be followed in all cases where river improvement is contemplated, for it would tend to obviate needless dissipation of our resources on economically unsound projects.

Problems of Drainage: Natural and Artificial. Even in those areas where man has not modified the physical environment materially, if at all, stream fluctuations may be great and overflow may be considerable during high-water stages of the rivers. Wherever he alters conditions by supplementing the natural drainage pattern with ditches and tile drains, for example, old problems are intensified and new ones are created. Not only is stream flow modified by these changes, but all forms of inland waters, including lakes, are affected, generally adversely. Some of these effects will be considered briefly in the part of this chapter which follows.

Floods and Flood Control. Floods are either gradual or rapid rises of river or other waters, most frequently caused by long continued or heavy rainfall, or by the sudden melting of snow when the ground is frozen. Occasionally, they may result from ice jams or violent winds, such as those of hurricanes. Man cannot cause floods, for there is no way in which he can introduce water into rivers in sufficient volume, nor can he duplicate other natural agencies competent to produce them. In floods of smaller streams, and those accompanying hurricanes or caused by other winds, rises may be sudden, but high-water stages of larger rivers commonly extend over a period several weeks in length, during which the rising water spreads gradually over the flat land which borders the normal river channel. This is the nature of the floods of the lower Nile Valley. These are the normal conditions in nature but, when man builds levees or embankments to confine stream flow, a break in such dikes may cause water to rise rapidly in areas adjacent to the crevasse, endangering life and causing great property loss.

Though man does not and cannot cause floods, many of his activities tend to increase their frequency and severity. The principal human activities which contribute to such results are deforestation of steep slopes; overgrazing of grassland and forest areas; unwise agricultural practices; and drainage, all of which tend to increase rapidity of runoff and thus intensify stream fluctuations. A forest cover, for example, retards runoff in several ways, but principally because the spongy litter on the forest floor absorbs the rain as it falls, feeding the water into the streams gradually. With removal of this cover, water runs off the bare slopes rapidly and river stages vary greatly. Overgrazing of grassland or forest, with destruction of the vegetation cover which

FIG. 174. Levee on the Mississippi River near Fulton, western Kentucky. The levee is at the right; the cultivated land, protected from inundation, at the left.

retards runoff, produces the same result. Unwise agricultural practices make soils hard and compact, so that they shed rather than absorb water. They may also furnish furrows as channels, thus facilitating runoff. If artificial drainage is necessary before the land can be brought into successful production, the results may be even more serious.

The average annual direct loss resulting from floods in the United States is estimated at $35,000,000; in years when they are above the average in severity, it is several times that sum. Direct damage is confined to the inundated areas and includes property loss; covering of previously productive fields with sterile mud; prevention of planting until too late to mature a crop; and other effects of similar character. It may likewise involve loss of life. The indirect and intangible losses are more widespread and even more serious than those resulting in the areas affected directly by flooding, as well as more difficult to estimate accurately. Indirect losses result from increase in soil erosion, clogging of reservoirs, decrease in the desirability of streams for all uses, loss of business with the flooded areas, and others. Flood losses, both direct and indirect, have increased greatly within recent years, with increased occupation of land subject to periodic inundation. Because of the widespread damage produced by floods, their control is not only a local but a national problem as well.

Though rivers of uniform discharge do not exist, the probability of destructive floods varies greatly in different drainage basins in the United States. Further, the extent of the damage varies equally, being greatest in the Lower Mississippi basin, where 40,000 square miles of land are subject to overflow, with high floods to be expected about every 13 years. In this area, though protected by a $300,000,000 levee system, the great flood of 1927, the most serious in American history, is estimated to have caused a loss of $250,000,000. In the Ohio basin serious floods are less frequent, but their control is more difficult than in the Lower Mississippi. When they do occur, they cause great damage in large cities such as Cincinnati and Louisville. The great flood of 1937, for example, inundated a total of 1,576,800 acres, 89,000 or 5.8 per cent in urban areas, and caused a loss of several hundred million dollars.

Flood Control. Though man can neither cause nor prevent floods, it is possible for him to control them to some extent, that is, decrease their intensity and prevent flood damage in part. Two contrasted sets of methods to accomplish these objectives have been proposed: one by engineers, a second by others.

The first set involves: (1) construction of higher and stronger levees; (2) straightening of river channels in certain places, to permit more rapid removal of flood waters; and (3) construction of spillways, or artificial channels, to divert part of the water from the river to selected areas, which will be inundated, thus preventing undue rise of the river downstream from the point of diversion. Levees are direct and obvious means

of preventing flooding of alluvial areas, and in common use in the Lower Mississippi Valley, where they were first constructed as early as 1717. However, they solve the problem only in part, for there are practical limits to their height, in addition to which they are enormously expensive to construct and maintain. Channel improvements alone are rarely, if ever, adequate. Spillways are helpful, but inhabitants of the areas designated for flooding object violently to having the river water diverted to their obvious, and often considerable, detriment.

The second set of remedies, those suggested by others than engineers, proposes retardation of runoff to regularize stream flow and thus smooth out flood crests, and the imposition of regulations in areas subject to floods. Such recommendations involve: (1) reforestation of steep slopes, (2) intelligent agricultural practices, (3) elimination of unwise drainage projects, (4) zoning and restriction of use of areas subject to floods, and (5) limited construction of retarding basins and storage reservoirs. An excellent example of the first of these last two means of lowering flood crests is afforded in the Miami Conservancy District in Ohio, where five retarding dams across the Great Miami and its tributaries, built after the Dayton flood of 1913, have so far been successful in preventing flood damage; of the second by Lake Mead, behind Hoover Dam in the Colorado River. Such dams are expensive, however, and their construction is rarely warranted for flood control alone.

Probably a combination of various methods is best in view of the desirability of regulating stream volume, quite apart from insurance against flood damage. This is because prevention of floods, checking soil erosion, and improvement of rivers for various uses are all related problems which can be solved best by feeding water into the rivers gradually rather than by concentrating solely on direct attempts to control stream flow. This latter procedure is desirable only to care for that fraction of the runoff which cannot be controlled to advantage. Where flood danger is excessive, indeed, it is probable that the land should be withdrawn from agricultural use and given over to forest.

Artificial Drainage and Its Effects. Wet land, or land needing drainage before it can be used effectively for agricultural production, falls into four general classes: (1) bogs, swamps, marshes, and wet land in glaciated areas; (2) low-lying alluvial areas and flat, poorly drained lacustrine plains, or former lake bottoms; (3) portions of coastal plains where natural drainage is poor, including tidal and salt marshes; and (4) irrigated land suffering from either alkalinity or waterlogging. All four are of limited value before drainage and their desirability may not be increased greatly, even by removal of the surplus water or alkaline salts. Drainage, designed to decrease detention of water, may serve either one or both of the following purposes: (1) malarial control, or (2) "nuisance abatement," that is, improvement of land values or recreational opportunity.

Drainage, including alkali removal in irrigated areas, becomes especially important if the land is already in farm use, and for reclamation of land not now in such use. Of the 86,967,039 acres of land in drainage enterprises in 1940, about 80 per cent of the total acreage was in occupied farms; slightly over 5 per cent was available for settlement; and over 20 per cent was idle. Our drained land is largely in the Lower Mississippi drainage basin, the Red River and Great Lakes basins, with much smaller percentages in the West, with drainage there largely to cure alkali conditions. The balance of the drained acreage is widely scattered. Most of the land easily drained in now under ditch.

In general, drainage or reclamation of wet land for agricultural use has not been profitable for initiators of the projects, though their loss may sometimes make later profitable use of the land possible. In Florida, for example, 5,699,022 acres have been drained, but of this acreage approximately 90 per cent is idle and unimproved and 51.2 per cent is tax delinquent. Even under the most favorable conditions, as in Mississippi, of the 2,290,618 acres drained, nearly 40 per cent of the total is idle and unimproved; and 4.6 per cent is tax delinquent. In many of the counties of northern Minnesota the costs of draining peat bogs, which have not passed into agricultural use, have bankrupted the counties in which the drainage projects are located. These are unfortunate conditions, made doubly so by the fact that artificial drainage, upsetting a natural balance as it does, always produces certain undesirable results. These include: (1) lowering of the ground-water level, (2) undesirable increase of stream fluctuations, (3) destruction of wild

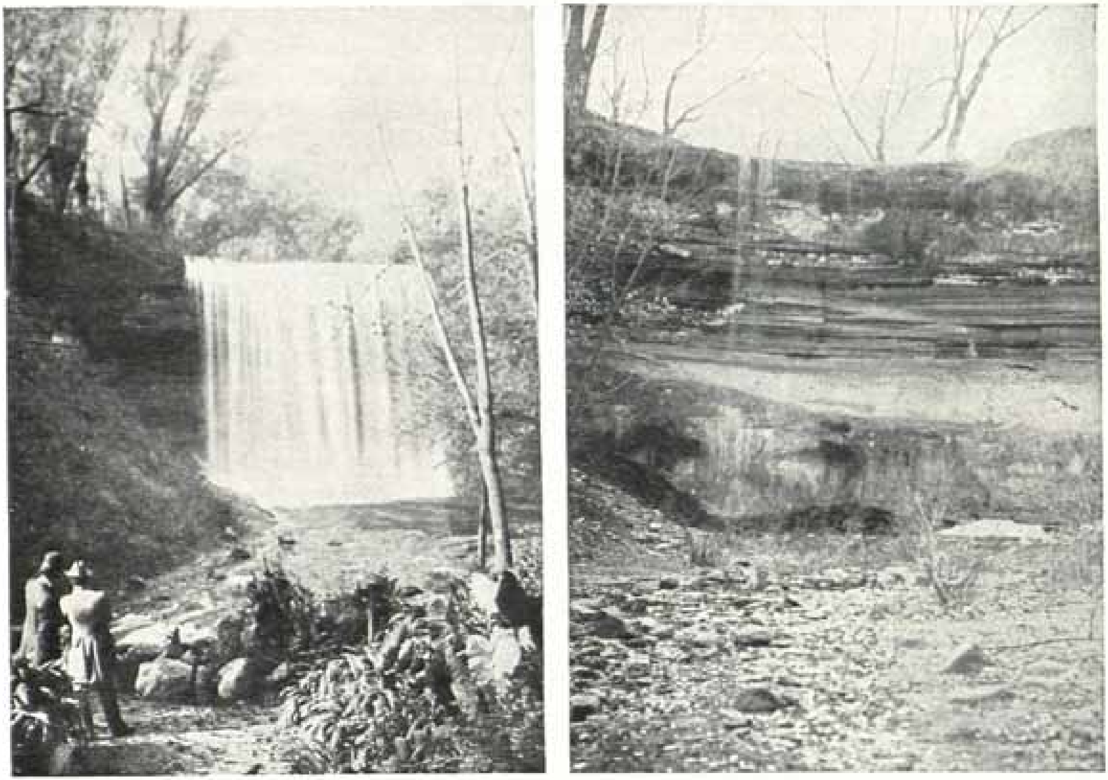

FIG. 175. At the left, Minnehaha Falls in the days before drainage robbed Minnehaha Creek of its water; at the right, the dry face of the Falls and the dry creek bed below, October, 1939, a dry year. Since that date, heavier precipitation has restored the Falls to something like their former attractiveness during part of the year.

life, both plant and animal, and (4) increased fire hazard.

Whether artificial drainage in any given area pays depends on the relationship between the benefits which accrue, if any, and the attendant disadvantages. Drainage, far in advance of any need of land for agricultural use, is always detrimental if reclamation is designed to bring additional land into production; drainage of land already in agricultural use may be desirable if costs are not excessive and the gains compensate for the inevitable losses. Whether this will be true varies from one locality to another; each problem of drainage is an individual case to be settled on its own merits. At present, those areas which can be reclaimed at a profit are perhaps a potential future, but probably not a great present asset.

Lakes and Lake Levels. A lake is a body of water of some size and depth standing in a depression which extends below ground-water level, the relation of lake level to that of the ground water being shown in the accompanying diagram, Fig. 176. If the depression is very shallow, a marsh or swamp rather than a lake results, since vegetation captures any wet area where the depth of standing water is slight. Most lakes are relatively small, occupying minor depressions in loose, unconsolidated material such as glacial drift, but a few are large and deep and their basins may be in part in solid rock. These basins are produced by various agencies. Some result from blocking of existing drainage lines and rectification of stream courses; some from crustal deformation. In greater number, however, they have been formed, at least in part, by glaciation. Therefore they are most numerous in glaciated regions.

All lakes are temporary phenomena in the life history of the drainage pattern of which they

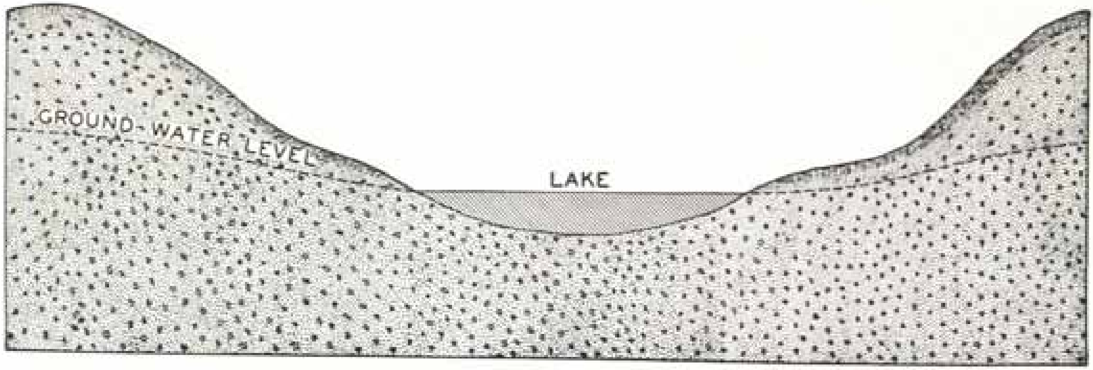

FIG. 176. Relation of ground water to lake level.

form a part, since the operation of natural agencies tends to destroy them, and all are, therefore, relatively short lived. Inlet streams, if present, bring in sediment, supplemented by slope wash, to fill the basins; outlet streams tend to drain them by vertical cutting. Waves and ice attack the shore lines, causing them to retreat, the material worn away from the shores in this manner being distributed over the lake bottoms, so that the lakes become both larger and shallower. When shallowing of water alongshore becomes sufficiently serious to interfere with approach by boat, the condition is frequently corrected by placing a dam in the outlet stream. This raises the lake level, it is true, but it likewise renews wave and ice attack on the shores, with additional enlargement and shallowing of the lake. With decreasing depth of water alongshore, vegetation establishes itself in the shallow water and the shore line becomes marshy. Then vegetation extends lakeward gradually as a floating mat, which eventually captures the entire surface of the lake, filling the basin and transforming what was a lake into a peat bog. This process is occurring in all marshy-shored, soft-bottomed lakes.

With construction of drainage ditches, lake destruction goes on even more rapidly, for the water which formerly found its way into the ground, to add to the store upon which lakes depend for their supply, now flows off at the surface and ground-water level is depressed. This lowering of ground-water level may be sufficient to shallow the lake to an extent that vegetation becomes established and causes its extinction. This has been the history of many of our smaller, shallower lakes after the initiation of drainage projects, one year often being sufficient to transform a lake into a marsh. In extreme cases, the ground-water level may be depressed so greatly that the lake disappears completely and cultivation of its former bottom becomes a possibility.

Even limited shallowing of lakes destroys much of their attractiveness, especially of those where depth alongshore increases gradually. In such cases, it decreases their area greatly, in addition to exposing the bottom, creating marsh conditions, and destroying the bathing beaches. These results are especially detrimental where resort possibilities furnish much of the basis for the regional economy. In such areas, it is hardly possible that any local benefits to be derived from drainage can offset the unfortunate effects upon lake levels, the destruction of the breeding places for birds, and the creation of unfavorable conditions for other wild life, both plant and animal.

When lake levels fall objectionably, it is often possible to restore them, at least temporarily, either by diversion of stream flow or by pumping water from artesian wells into lakes, the levels of which it is desired to raise, though the economic soundness of either of these two procedures may be open to question. The second of these two methods has been used for restoring the level of Lake Minnetonka, west of Minneapolis, during dry years, when a considerable investment in summer and all-year homes was threatened by exposure of the lake bottom and marsh growths in the shallow water alongshore. Unfortunately, however, this pumping caused many wells in the surrounding area to go dry, which worked a hardship on users of their water.

When lake level falls to the extent that a marsh results, it is possible, if ground-water level has not been lowered too greatly, to restore a lake

by deepening its basin sufficiently so that water again stands in the depression. This has been done in Minneapolis for several small lakes such as the Lake of the Isles, Nokomis, and Hiawatha, in the public park system, but it is much too expensive to be a general remedy. These steps, it will be noted, have been made necessary in considerable part by poorly conceived activities of man, supplemented to some extent by an accumulated deficiency in precipitation.

Man and His Use of Inland Waters. The varied values and potentialities of inland waters under intelligent use are obvious. It is further apparent that, where they are used unwisely, results may be very unfortunate. Therefore, such change as is contemplated as a means of improving our inland waters should be considered, not only with respect to its direct, but to its indirect effects as well. The various aspects of river improvement should, then, be considered as parts of a related whole and, in turn, as a portion of a still larger pattern embracing the total of human use of an area. Intelligent planning for desirable use of inland waters, therefore, must be based on more than superficial information. The history of the past demonstrates this to be a fact, though in some of the so-called "planning," and particularly in that of interested groups, either majorities or minorities wishing to establish some social or economic theory, or secure unfair personal advantage, the teachings of experience have been disregarded. Such being the case, the future undoubtedly holds unpleasant surprises in store which might have been avoided if more mature consideration and good judgment had been exercised in the past.

QUESTIONS AND EXERCISES

1. Name the principal miscellaneous uses of our rivers and lakes. Which ones of this list are the more important?
2. What are the various types of fishing in our inland waters? Which one of these is of relatively little importance in this country but very important in eastern Asia? Why?
3. In what parts of the world are inland waters used in an important way as the location of habitations for floating populations? Why? Why not used to such an extent in most parts of the United States?
4. What various uses do the canals of the Netherlands serve?
5. What are the different recreational uses of our inland waters? Why do rivers and lakes offer greater opportunity for recreational use in glaciated areas than in the South?
6. Report on the resort industry at Lake Tahoe.
7. Discuss the development of resort possibilities in the Detroit area and its basis. Why has this been a relatively recent development?
8. Why are the recreational values of the lakes and rivers locally of great relative as well as actual importance in the cutover areas of the Lake States?
9. Discuss the importance of the resort business in Michigan, Wisconsin, and New England. In what other states is this industry highly developed?
10. What steps should be taken to preserve the natural advantages of our inland waters as recreational assets?
11. Why is it desirable to consider river improvements for various uses as a group rather than to attack the problems of river use singly?
12. What are the objectives of the Hoover Dam project? How does this project illustrate a desirable procedure in river improvement?
13. What is a flood? What causes floods? Why is it impossible for man to prevent floods?
14. Why is river rise generally gradual in normal floods of large rivers? Is it ever rapid in rivers and, if so, under what conditions? How does construction of levees affect the character of floods?
15. What effect do man's activities have on floods? What are these activities which affect floods? What effect do they produce? Why?
16. Discuss flood damage in respect to character and amount. Which is more serious, the direct or the indirect damage? Why?
17. Do all rivers flood badly? Why? In what parts of the United States are floods most common and disastrous in their effects? Why?
18. What is meant by "flood control"?
19. What two general methods of flood control are available? What is the fundamental difference between the two methods?
20. State the methods of controlling floods suggested by engineers. To what extent are such methods desirable?
21. State the methods of flood control suggested by those who are not engineers. Why are these desirable, quite apart from their effect on floods?
22. What types of land need drainage? What are the purposes of artificial drainage?
23. State the unfavorable effects of artificial drainage.

24. Discuss the desirability of artificial drainage for reclamation, including the effects of such drainage in Florida, Mississippi, and Minnesota.
25. What is a lake? What is the difference between a marsh and a lake? Between a swamp and a marsh?
26. What natural agencies operate to destroy lakes? How do they operate and what effects do they produce? Why do lakes tend to become larger and shallower with the passage of time?
27. How does artificial drainage affect lake levels adversely?
28. If lake levels become depressed, how may they be restored? Why is this economically impossible on a large scale?
29. In what types of areas is the lowering of lake levels particularly serious? Why?
30. What procedure is necessary if we are to retain our lakes at their present levels, and in their present condition?

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Report of the Water Planning Committee of the National Resources Board, Washington, 1934, Part III, Section II, Parts VII, X, XII.

These parts of the report listed are devoted to flood control, drainage, and recreational use of inland waters.

Parkins E. A., and Whitaker, J. R., *Our Natural Resources and Their Conservation*, John Wiley and Sons, Inc., New York, 1939, Chaps. VIII, XV, XXI.

The chapters cited afford an excellent discussion of reclamation of wet and overflow land, and of floods and flood control, in addition to a limited consideration of the recreational values of inland waters.

Chapter Twenty-Two

SURFACE FEATURES: LOWLANDS

Effects and Subdivisions of Land Forms. Man's activities are affected, not only by the surface features of his immediate surroundings, but by those of adjacent areas as well. The first limit land use and local circulation; the second affect accessibility and the possibility of gainful exchange with other regions, either near by or far away. It is, therefore, not sufficient to consider local conditions only in a comprehensive evaluation of areal opportunity as influenced by topography.

Two major classes of land forms may be recognized: lowlands and highlands. The former are normally plains areas; the latter may be either plateaus or mountains, dependent on their past geological history. These designations, "highland" and "lowland," are comparative terms like "large" and "small," "tall" and "short," "rich" and "poor," for they refer to relative as well as actual elevation. Thus a low highland may be higher than an immediately adjacent lowland, yet be of lower elevation than a high plain associated with a major mountain uplift. The essential facts to be kept in mind are that all lowlands are of relatively slight local relief and of lower elevation than the highlands which adjoin them, but that there is no arbitrary lower elevation for highlands and, similarly, no definite upper elevation for plains areas.

Classes and Characteristics of Lowlands. Lowlands may be subdivided into the following, not always mutually exclusive, types of plains: (1) coastal, (2) alluvial, (3) glacial, (4) lacustrine, and (5) degradational. This classification is based on the origin of such surface features as local relief, soils, drainage, and other environmental aspects which affect opportunity. In the first four of these types of plains, the surface features result largely from constructional, in the last, principally from destructional, processes. All five, however, have common characteristics which justify their inclusion under the major subdivision, lowlands. All, for example, are areas of relatively slight relief, that is, surface irregularity is not great. This favors agricultural use of the land and internal communication. In all, rivers tend to flow sluggishly, making them more suited for use in navigation than for power development, except occasionally in glacial plains, where drainage is immature. All likewise lack marked surface differences over relatively large areas. These are features facilitating exchange of goods and ideas and making for progress.

That lowlands are attractive to man and that they offer opportunity is indicated by the fact that such a large fraction of the world's inhabitants lives in plains areas. In the United States, for example, it is estimated that approximately 90 per cent of the total population occupy areas of such slight elevation and relief that they may be classified as plains. This density of population in lowland areas is much too great to be purely accidental, especially in view of the fact that concentration in plains areas is similarly marked for all parts of the earth's land surface. Highlands the world over, by contrast, are commonly occupied by sparser and weaker populations, generally forced into these less desirable areas by stronger groups, which displace them in the more promising plains. Thus, in India, the Bhils and Gonds occupy the hilly, poorly watered, south-central Deccan; in China, the aborigines live in the southwestern provinces, in the rough country south of the Yangtze. In the United States, we have similarly dispossessed the Indian, forcing him by stages into the relatively less desirable, in considerable part, highland areas, with passage of the better plains into white ownership.

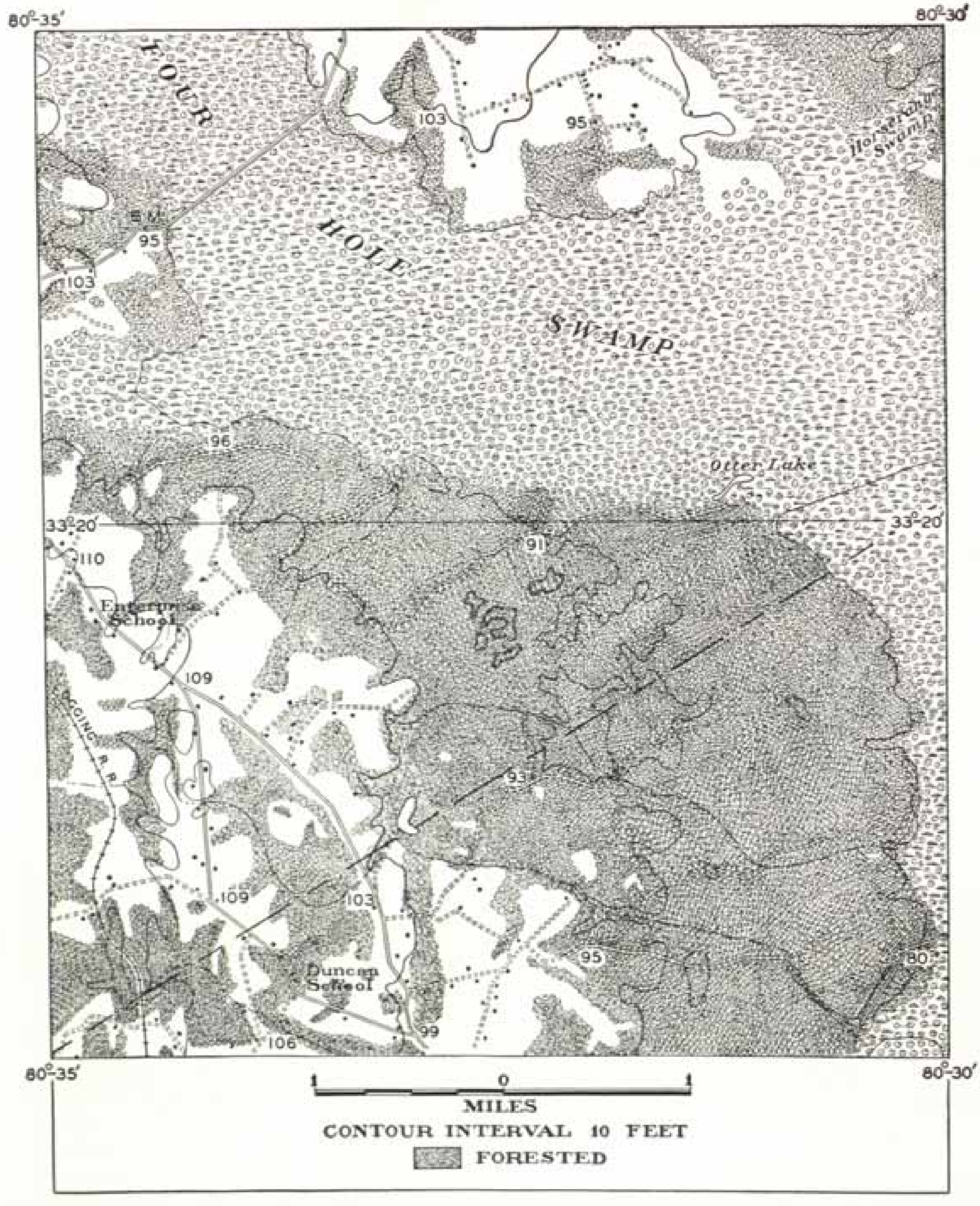

Fig. 177. A portion of the Atlantic Coastal Plain, drained by the Edisto River and its tributaries, about 25 miles northwest of Charleston, South Carolina. Elevation is slight; soils are sandy; natural drainage is poor. Nearly 50 per cent of the area is in swamp and approximately 75 per cent in forest, swamp and upland types. These are typical conditions for the outer margin of the coastal plain bordering the Atlantic seaboard. (After Bowman Quadrangle, South Carolina, U. S. Geological Survey.

Coastal Plains. A coastal plain is an area which has been added to the land mass of which it is today a part largely by exposure of former ocean bottom. Immediately offshore, bordering the Atlantic and Gulf coasts of the United States, and other continental margins as well, the water is relatively shallow over what is known as the "continental shelf." If this portion of the ocean bottom were uplifted as much as 600 feet, or the ocean surface were depressed by an equal amount, the continental shelf would become dry land. In past geological time such an elevation of the ocean bottom occurred along our eastern seaboard, forming what is known as the "Atlantic and Gulf Coastal Plain." Prior to this uplift, the old seacoast extended southerly from New York City through the sites of Trenton, Philadelphia, Baltimore, Washington, Richmond, Raleigh, Columbia, Augusta, Macon, and Montgomery. Then the coast line swung to the north to form a great embayment into which the Mississippi River discharged near its present junction with the Ohio, from which point the trend of the coast was southwesterly to the Mexican boundary and beyond. The area which lies between this old coast line and that of today is the Atlantic and Gulf Coastal Plain.

This plain is of slight elevation in most portions; even on its inner margin, where uplift has been greatest, elevations are seldom as much as 600 feet. Near the coast, in Florida, much of the land is only a few feet above sea level. On its outer margin, bordering the ocean, the land is flat and swamps are common, some, such as the Everglades in southern Florida, the Great Dismal in Virginia and North Carolina, and the Okefenokee in southern Georgia and northern Florida, being of great extent. Further, local subsidence subsequent to uplift has caused drowning of some land previously near sea level, and embayment of certain of the rivers such as the Potomac and James in Virginia. On its inner margin, where elevations are greater, the country is gently rolling, or it may even be distinctly hilly, but, though slopes may be steep, hills are not high, for elevation is not great, seldom as much as 600 feet. These are common surface features of all such plains.

The surface of the coastal plain, underlain everywhere at slight depth by unconsolidated or but slightly consolidated rock, continues seaward with no great break into the present-day continental shelf. Over the submerged surface of this shelf, coarse material, contributed by rivers and wave action, is spread to obliterate inequalities of the ocean bottom; most of the clay is dropped in deeper water, farther from the shore. Thus, except in sheltered bays where some of the finer material may be deposited or in localities where marine forms of life may leave calcareous or limey remains, the ocean bottom immediately offshore tends to be sandy. For this reason, soils

FIG. 178. Hilly topography of the inner margin of the Gulf Coastal Plain in the Gulf Embayment region of western Kentucky. Soils are thin on the steep slopes, too thin to tempt agricultural use. Therefore they remain in forest. Along the roadside in this view, soils are not more than 6 inches thick; the roadbed is solid rock. Under such conditions, agriculture, confined to small tracts of level land in depressions and along streams, is limited and returns are poor.

of coastal plains, formed by exposure of former ocean bottom, are commonly sandy and poor. In the Atlantic and Gulf Coastal Plain, an exception to this rule is afforded in limited areas such as that around Selma, Alabama, where the original soils, today largely removed by erosion, were formed by disintegration of impure limestone and under a grassland cover.

Streams flow sluggishly over the flat surface of coastal plains. Therefore the larger rivers are commonly navigable, though not well suited for development of power. This is particularly true where drowning has embayed and tides affect their lower courses. This embayment was of great importance to the early settlers of Tidewater Virginia, since it enabled the small ships of that period to tie up at the plantation docks to take on and discharge cargo. Today, these same wide rivers and the great swamps interfere with communication by land, both by road and rail. Therefore rivers still continue to function as highways to a much greater extent than in most parts of the United States. However, despite their sluggish flow, the shallow valleys streams have cut are the most marked surface irregularities of coastal plains.

Because of the generally sandy soils, together with a serious soil-erosion problem in the hillier areas of greater elevation, coastal plains, even with a favorable climate, generally rank low in agricultural desirability. For example, though the Atlantic Coastal Plain was one of the areas of earliest agricultural settlement in the United States, there is frequently little to indicate that fact today, for a large fraction of the formerly cultivated area long ago reverted to forest, and only slight agricultural use of the land is evident at present in many areas formerly under cultivation.

Though coastal plains in all parts of the world are similar in location with reference to the ocean, topography, and drainage, they are not alike in many fundamental respects, for they differ in accessibility, climate, soil types, and in stage of development. This causes great variation in density of population and in kind and degree of economic activity. In many coastal plains, agriculture is locally important and often the dominant occupation, but this is far from being universally true. Occasionally, in less developed areas, man may depend on forest industries or even on hunting and nomadic grazing, as do the

Fig. 179. Sandy soils, climate, and topography favor market and truck gardening in limited portions of the Atlantic Coastal Plain, where facilities for marketing the crop are available. In this view in Norfolk County, Virginia, where these conditions exist, the crop being harvested is spinach. (Courtesy of the Norfolk Advertising Board.)

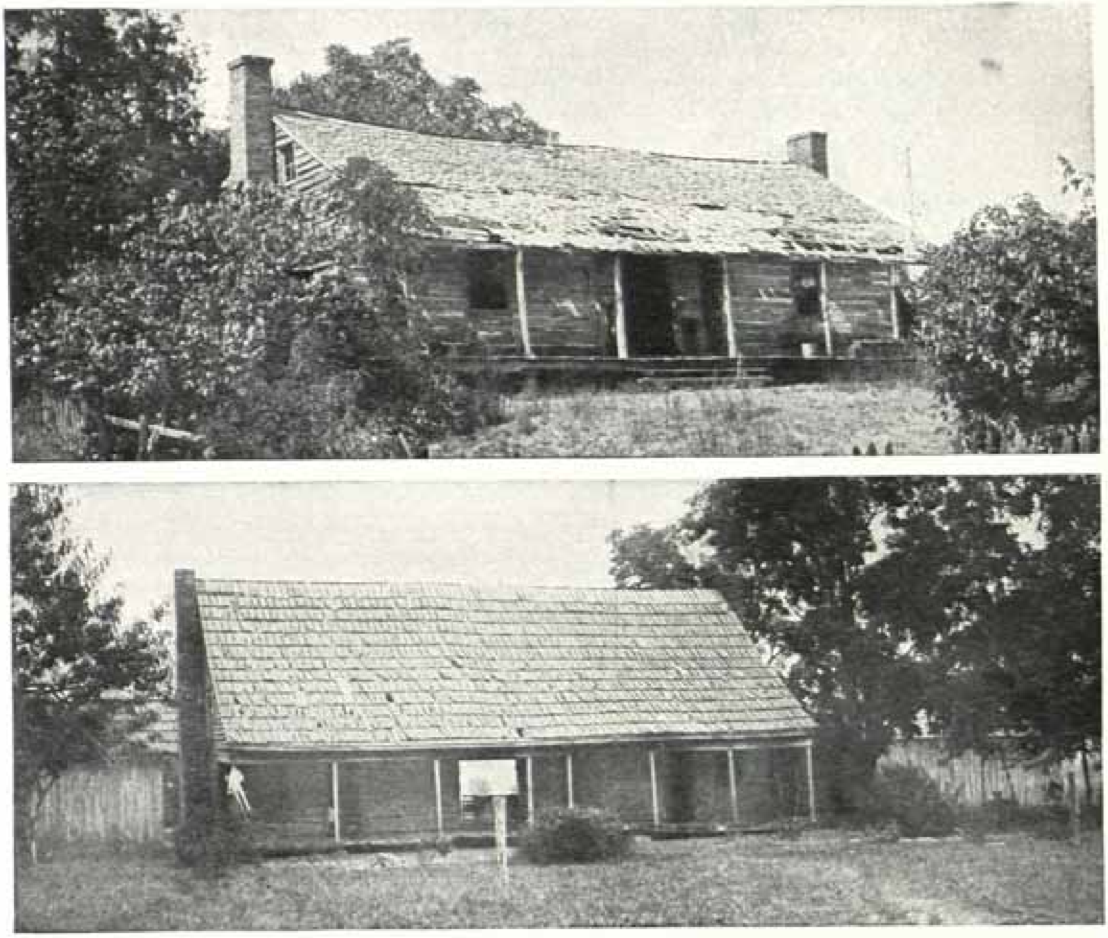

FIG. 180. *Top:* This house, in the hilly inner portion of the Gulf Coastal Plain of McCracken County, western Kentucky, is typical of many in the poorer parts of the area. Of log construction, with roof of hand-split shingles, though occupied, its dilapidated appearance might suggest abandonment.

Bottom: An attractive "dog trot" log house on the inner margin of the Coastal Plain, Marshall County, western Kentucky. It consists of two separate log houses under a common roof of hand-split shingles. A floored passageway between them, the "dog trot," finds use for various household purposes. This is a rather common type of log house in many parts of the South.

Nentsi, who inhabit the frozen plains of northwestern Siberia. Again, a favored location with reference to the sea and access to markets may lead to important commercial and industrial development, a dense population, and a high degree of urbanization. Thus several types of coastal plains might be recognized but, because practical considerations prevent extended consideration of the varied possibilities, discussion will be limited to a statement of some conditions in the Atlantic and Gulf Coastal Plain, to which prior references have been made.

In this particular coastal plain, lumbering and other forest industries are still important, both on the uplands and in the swamps; often they are locally the major economic activities. This region has a cutover-land problem comparable in seriousness to that of deforested areas in the North, for here, also, profitable agricultural use of the land does not necessarily follow lumbering operations. Frequently, indeed, tree crops are the only ones which can be grown to advantage, though this is a low-return use of the land. In certain portions, where access to markets, plus favorable soil and climate permit, a garden type of agriculture may be profitable, for example, in the Norfolk

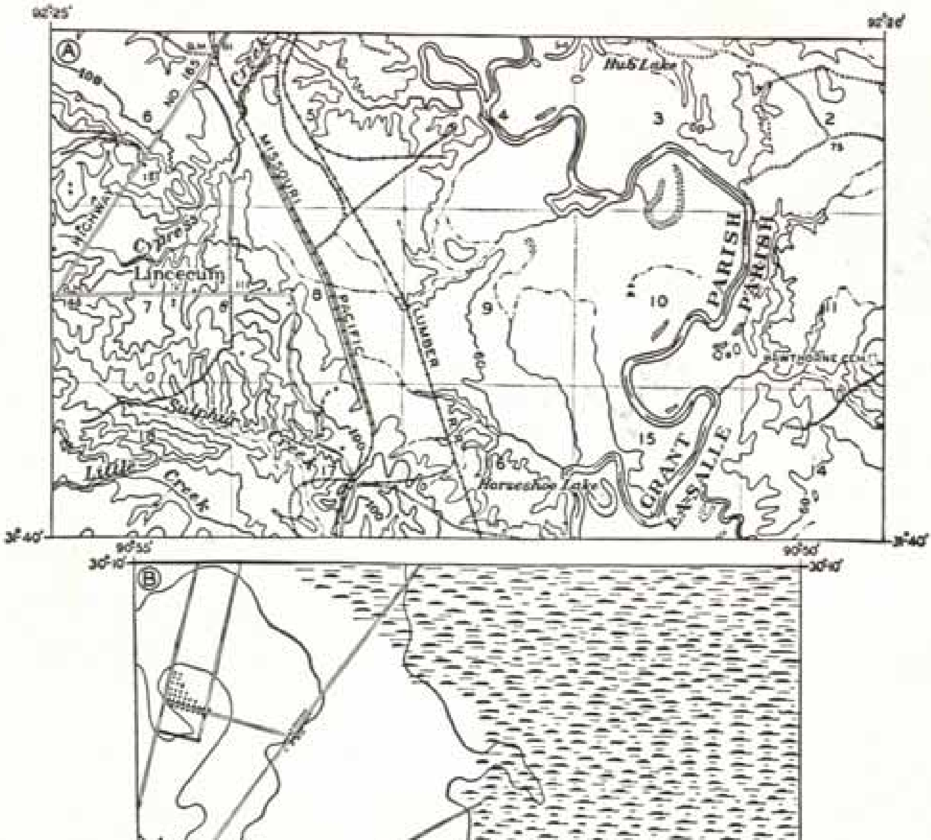

FIG. 181. *Top:* Alluvial plain of a small stream, the Little River, in central Louisiana. (After Pollack Quadrangle, U. S. Geological Survey.)

Bottom: Alluvial plain of the Mississippi River in southeastern Louisiana. (After Donaldsonville Quadrangle, U. S. Geological Survey.)

region of Virginia and the tobacco-growing areas of both Virginia and the Carolinas. Similarly, the production of subtropical crops and fruits becomes important in Florida, but only a small fraction of the available acreage can be used profitably for these purposes. In limited areas, also, in Florida and along the Gulf Coast, mild winters have made possible the development of an important winter resort business. In most parts of this coastal plain, however, absence of opportunity contributes to perpetuate poor living conditions, this part of the South being a home of the "poor white" and the "cracker."

The Atlantic and Gulf Coastal Plain is not highly urbanized, the few cities of any size, located at seaboard, serving primarily as outlets for the interior. Though seaports, these cities are commonly handicapped by poor and shallow harbors, plus the fact that they are often not on main, but spur rail lines. Consequently, few are large, unless important resort centers such as Miami, Florida, or some with good harbors and affording the only effective outlet for some product such as coal, like Norfolk, Virginia. Thus, from Norfolk to Jacksonville, on the Atlantic coast, there are no urban centers with populations in excess of 100,000. Similarly, there is none of 100,000 or more inhabitants between Tampa and New Orleans.

Alluvial Plains. In a normal river valley the stream course is bordered by flat land subject to inundation at high-water or flood stages. This flat land, subject to periodic overflow, is known as an "alluvial plain"; remnants of old alluvial plains, at higher levels, are known as "river terraces." Plains of this type are narrow along small streams, but those which border the lower courses of the Mississippi, the Nile, and other large rivers may be several miles in width. In all cases they are formed by river action, being widened by lateral cutting where the river swings against the valley wall; aggraded or built up vertically by deposition during flood stages; and lengthened by delta building if the river discharges into some body of water. Some of these deltaic deposits, such as those of the merged delta of the Rhine, Meuse, and Scheldt rivers in the Netherlands, and of the great compound delta of the North China Plain, are of considerable areal extent and support large populations. A corresponding deposit on land is known as an "alluvial fan." If such fans, formed at the base of steep slopes, particularly in dry areas, are numerous and coalesce, they produce an extensive deposit of alluvial material known as a "piedmont alluvial plain," because of its location. An example of such a plain is afforded by the Valley of California, between the Coast ranges and the Sierras. In this valley, filled by wash from the mountains which border it on the east and west, the Sacramento and San Joaquin rivers have built alluvial plains, in places of considerable areal extent, from reworked material of the fans. These plains have been mentioned earlier, in Chap. XIX, in connection with discussion of the Central Valley project. Where alluvial plains border streams which cross a coastal plain, the trend of the alluvial deposits is normally at right angles to that of the "belted" soils formed from the uplifted or exposed marine sediments.

The surface of an alluvial plain slopes gently away from the natural levee, built by greater deposition where overflow begins, and thus located near the river, toward the valley walls, bordering which swamps are of common occurrence. Relief is slight, the only surface irregularities being depressions left by natural rectification or straightening of the stream course, and bordering crescentic ridges, old natural levees. In a narrow belt paralleling the river, and on the scattered remnants of old natural levees, soils tend to be sandy, such coarse material being dropped near the point of overflow. Farther from the stream, and especially near the valley walls, the soils are finer in texture and commonly clays, which settle from suspension slowly. Except where old, badly leached, and highly oxidized, soils of alluvial plains of the larger rivers are commonly not only fine textured and thick, but fertile as well. This is because their parent material is largely topsoil, high in organic content, derived from various sources, and not subject to erosion. The word "valley" connotes fertility because of these facts, for alluvial plains are associated with valleys like that of the Nile, one of the garden spots of the ancient world where Western civilizations had their beginnings. The older alluvial deposits such as some in the Indo-Gangetic Depression of northern India, and of the Po Plain in northern Italy, are, however, much less desirable for agricultural use.

As a result of topography, drainage, both natural and artificial, is away from the rivers toward the swamps near the valley walls and, from there, roughly parallel to the stream course.

FIG. 182. *Top:* Living conditions, undrained alluvial plain of the Mississippi River.
Middle: Clearing and house set on posts on a natural levee, undrained alluvial plain of the Mississippi River.
Bottom: Schoolhouse set on posts to avoid flood damage, undrained alluvial plain of the Mississippi River. School is in session in August, since roads are under water in the spring.

until downstream junction with the river becomes possible. Subject to danger of periodic inundation, unless under levee, such plains are frequently too wet when undrained to be used effectively for agriculture, even on the sandier, higher natural levees which afford the only feasible sites for occupation. Therefore much of their surface, particularly in the swamps, remains in forest. Where undrained, opportunity is limited, malaria is often prevalent, population is sparse, and living conditions are poor. The great river swamps of the southern United States still remain one of the wildest parts of our country, and one of the few places where predatory animals still exist in considerable numbers. With protection from overflow, however, the alluvial plains of our larger rivers pass into profitable agricultural use in those areas where climate is favorable, often at very small costs for reclamation. These overflowed areas comprise the bulk of our potential agricultural land capable of profitable reclamation by drainage, if need for additional land for production should arise.

Before protection from danger of periodic overflow, areas under settlement tend to be linear in form and confined to the natural levees along present stream courses, with scattered occupation of similar sandy ridges elsewhere. This pattern of distribution is especially marked in the Lower Mississippi Valley, where the first settlement occurred at a very early date, with rivers the highways. In this area, farms front on the river and extend back into the swamps, with the present-day main highway located on the natural levee, paralleling the river. Subsequent to drainage, this peculiar pattern of occupation may be absent except as an inheritance from the past in the areas of "shoestring" farms to which reference has been made.

All alluvial plains are similar in origin, topography, drainage and, to a lesser extent, in soils, but they differ from one another in their vegetation cover because of variation in climate, and they vary correspondingly in potentialities and use. In general, they are desirable areas, with agriculture the major economic activity. In the past, some were the locations of the earliest of civilizations; today, such plains support some of the world's densest populations, for example, those of China and India. Within the period of history, at least, the most favored alluvial plains, like those of the Nile, Tigris and Euphrates, Ganges, and Yangtze, have been foci of attraction, tempting invasion by less fortunately located populations.

Cities located on alluvial plains subject to overflow are faced by certain problems, difficult of solution. Danger of flood is always present. If only in part on the plain, with the better residence sections on the upland, heavy grades be-

Fig. 183. Alluvial plain of the Mississippi River under levee. Only a few miles from the undrained area shown in Fig. 182. All the land is in production, with cotton the major cash crop.

tween the two parts of the city are inevitable, and danger of inundation still confronts the business and poorer residential areas whenever river levels rise above those of the streets. During flood stages, water supply is often polluted; it is difficult to dispose of sewage; and burial of the dead as practiced elsewhere is impossible. At all times, satisfactory foundations for office buildings and other heavy construction are difficult to secure in the loose, water-filled alluvium. River attack on the city site is continuous and so damaging at high-water stages that artificial protection of the shore line is necessary to prevent caving of the river banks and property loss. Further, all great meandering rivers, such as the Mississippi, are subject to changes of course which may leave a city, formerly on the river, some distance from the main stream. This eliminates benefits which may accrue from being located on a navigable waterway and necessitates possible construction and always maintenance of artificial connection with the river channel, unless use of the river is to be lost. Though all these problems can be met and solved more or less effectively, they nevertheless constitute a handicap to cities located on alluvial plains.

Glacial Plains. During comparatively recent geological time, the Pleistocene period, northwestern Europe and northeastern North America were covered to great depths by ice moving outward from centers of dispersal in the north. (See Appendix, Fig. 460.) As these ice sheets advanced, they carried with them rock material scoured and plucked from areas overridden by the continental glaciers, material which was deposited with melting of the ice sheets and retreat of their fronts. Lowland regions veneered by such deposits, like those of the larger portion of the Lake States, are known as "glacial plains."

Topography, soils, and land use in these plains vary with the character of the deposition. Wherever the ice sheet halted for long periods of time, melting caused accumulation of rock debris along its front and the formation of a range of hills known as a "terminal moraine" because of its location. Such a moraine is hummocky in character, with summit levels of the hills differing, and with lakes of common occurrence, since many of the depressions extend below groundwater level. The soils of such moraines may be either clay or sand and gravel. Where melting was slow, so that only a small amount of water ran away from the ice front, little or no sorting of material occurred. There, the terminal moraine is a heterogeneous deposit. In such moraines, soils may be productive, but steep slopes and numerous boulders, plus the ever-present danger of erosion, may interfere with agricultural use of the land. Where melting of the ice was more rapid, sorting of the deposited material occurred and soils are sandy and gravelly. Such soils are of low productivity and topography is unfavorable for general farming, but orchards do well on the naturally well-drained slopes, and protection from frost damage is assured by effective air drainage. Therefore they sometimes find use for fruit production.

When the ice halted, during the formation of one of these terminal moraines, water ran away from its front, often carrying much coarse material in suspension, only to deposit it in the form of an outwash plain sloping gently away from the terminal moraine, when velocity of flow was checked. In general, such deposits are flat, but occasionally they may be pitted by minor depressions in which marshes or shallow, sandy-bottomed lakes occur, if the depressions extend below ground-water level. Outwash plains are topographically suitable for agricultural use, but they suffer from poor, sandy soils, not adapted to general farming, though locally valuable for truck gardening, since they warm rapidly and permit early planting. In limited areas, in the small prairies where a grassland cover improved soils, agricultural desirability is greater. In regions where these sand plains are not favorably located with reference to city markets, and especially under a coniferous forest cover, they pose a serious problem of land use, probably best solved by growing a forest crop.

Where the ice front retreated rather rapidly, deposition left a gently undulating land surface known as a "till plain" or "ground moraine," with occasional lakes in shallow depressions. Topographically, such plains are well suited for cultivation; and soils are of satisfactory textural characteristics, as well as generally of high productivity. Except as occasionally stony, or handicapped by climate, they permit profitable agricultural use, much of the most desirable land of the Corn Belt being till plain.

The deposits left by the ice filled depressions and buried valleys with glacial drift, so that the present topography and river pattern bear no

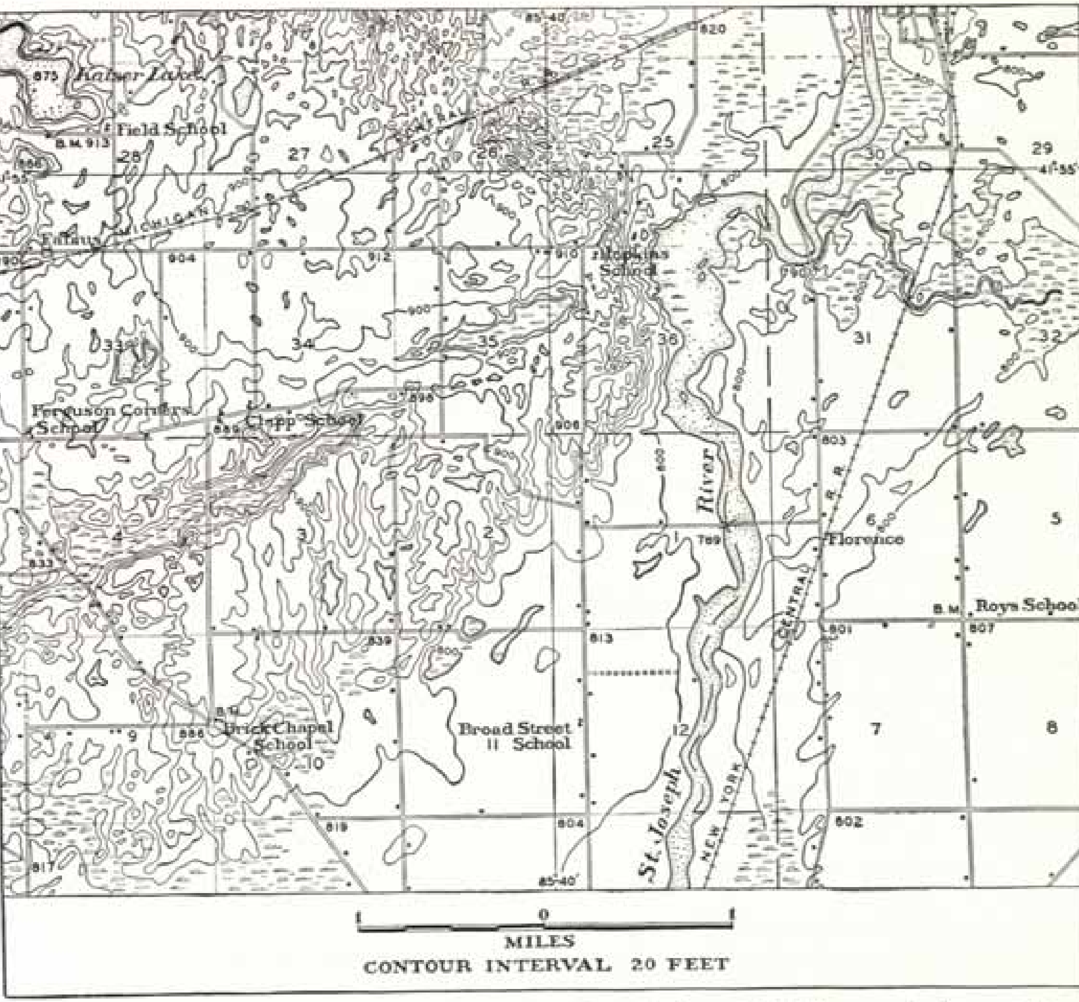

FIG. 184. A glacial plain in St. Joseph County, southern Michigan. The hilly area in the west is terminal moraine; the flat eastern part is outwash plain. Natural drainage is poor everywhere. There is only one river, and it has no tributaries in the area mapped. Shallow depressions in both the outwash plain and the terminal moraine are occupied by marshes; in the moraine, the deeper pits hold lakes. Widening of the river results from damming, not from natural conditions. This is not a good agricultural region, for both the outwash plain and the terminal moraine have sandy soils. (After Three Rivers Quadrangle, U. S. Geological Survey.)

relation, except accidentally, to those of the period prior to the ice invasion. The present rivers and lakes are, therefore, a development subsequent to retreat of the ice and exposure of the land surface. Thus the rivers are young streams, with few tributaries. They are likewise often interrupted by rapids and falls which interfere with navigation, but are valuable for power development. Interstream areas are poorly drained in the absence of a number of tributaries adequate to carry off surplus water. Shallow depressions are occupied by marshes and swamps, or peat bogs; deeper basins, by lakes, for the processes of filling by sediment and drainage by cutting of outlet streams have not progressed far as yet. In view of the poor natural drainage, ditching and tiling are frequently necessary before the land can be brought into effective use. Therefore many of our present operating drainage projects are in glacial plains areas, as in the Lake States.

Land use in glacial plains may be handicapped

FIG. 185. Outwash plain and gravelly terminal moraine in St. Joseph County, southern Michigan. The hummocky moraine in the background marks the place where the ice front halted. As the ice melted and the water ran away from its front, it deposited the gently sloping outwash apron in the foreground. Much of the moraine is still in timber, but the flatter outwash, though sandy, has passed into agricultural use.

locally by unfavorable topography and stony soils, sometimes to an extent that profitable agricultural production is difficult or even impossible. Elsewhere, sandy soils may impose a limitation, or drainage may be necessary where natural runoff is inadequate. Patchy distribution of land forms and soil types likewise often interfere with effective agricultural use. Taking all factors into consideration, however, it is believed that glaciation has, in general, been beneficial in glacial plains areas. This belief is based on the fact that the Driftless Area of southeastern Minnesota, southwestern Wisconsin, northeastern Iowa, and northwestern Illinois is less productive on the average than bordering portions of the glacial plains.

Lacustrine Plains. Lacustrine plains are formed by exposure of lake bottoms of considerable areal extent. Outstanding examples of such plains in this country are afforded by the Red River Valley of the Dakotas, Minnesota, and Canada, the former bottom of glacial Lake Agassiz, and by the partially exposed bottoms of lakes which formerly occupied portions of the present-day Great Lakes and their larger bays, toward the close of the Pleistocene period. When the continental glacier retreated northward, these lakes were partially drained by the melting of ice dams

FIG. 186. A view across Pigeon Prairie, in southern Michigan, on the Chicago Turnpike. In the background is the terminal moraine; in the foreground, the outwash plain, here of more than average agricultural desirability because of the original grassland cover. Because of its greater promise, this was one of the areas of early settlement in southern Michigan.

FIG. 187. A prosperous dairy farm in the gently rolling till plain of southern Wisconsin. (Courtesy of the Wisconsin Department of Agriculture and Markets.)

which impounded their waters. In the case of glacial Lake Agassiz, which occupied the present Red River Valley, the ice barrier to the north prevented north-flowing drainage from reaching Hudson Bay, as it does today, so that water accumulated in front of the ice dam, covering the land until it formed a lake larger than all the present-day Great Lakes combined. Eventually, its waters rose sufficiently to overflow to the south, through the valley of the present-day Minnesota River, into the Mississippi. Disappearance of the ice dam to the north, with amelioration of the climate at the close of the Pleistocene, allowed resumption of north-flowing drainage, thus destroying the lake. Lakes Winnipeg and Winnipegosis are its shrunken remnants, in the deeper undrained depressions. Some of the smaller and less important lacustrine plains were formed by cutting of outlet streams, plus possible lowering of ground-water level. This was the cause of the destruction of Lake Aitken in the county of the same name in Minnesota, its former bottom today being crossed by the Mississippi River, which assisted in its destruction.

These lakes, in existence for long periods of time during the close of the Pleistocene, had normal bottom and shore-line features which still persist as surface expression. Since the lake bottom was flat, the same is true of the lacustrine plain, its monotonous surface being interrupted only by shallow stream valleys, developed since exposure, and by occasional rises representing

FIG. 188. Exceptionally stony moraine in Sweden. Such land cannot be plowed and is of value only for pasture.

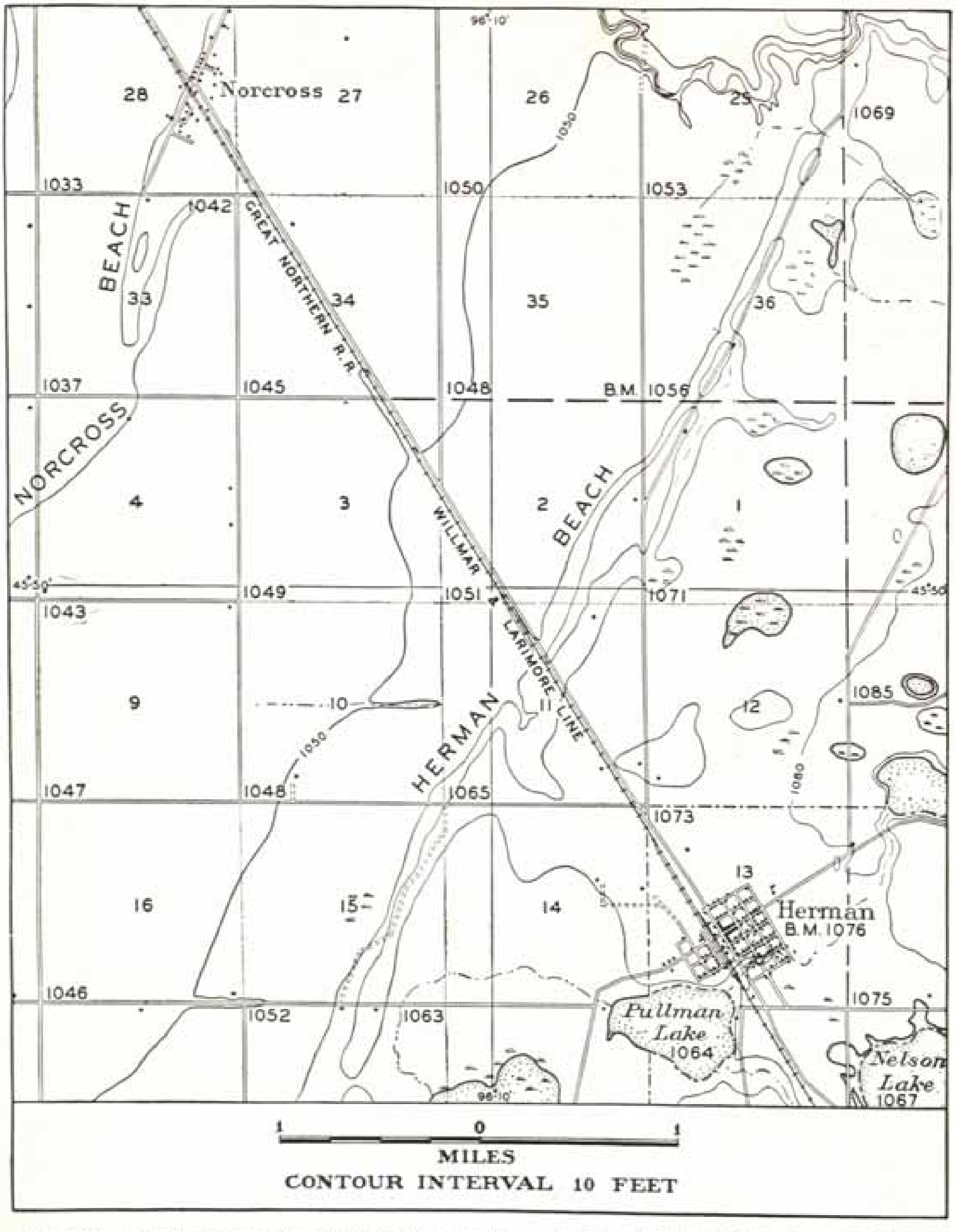

FIG. 189. A portion of the Red River Valley, the former bottom of glacial Lake Agassiz. This is an area of slight relief, with only minor surface irregularities introduced by the two beach ridges and a shallow river valley. Natural drainage is poor. Therefore the towns, Norcross and Herman, are located on the somewhat higher, sandy, better drained beaches. Roads on the flat lake bottom generally follow section lines, but one runs runs diagonally along the Herman Beach, where natural drainage is better. (After Herman Quadrangle, Minnesota, U. S. Geological Survey.)

sand bars and other depositional forms near, and low beach ridges or dunes along the former shores.

Along the old shore lines, soils are sandy; farther out on the old lake bottom, they are poorly drained, heavy clays. The poor natural drainage, in combination with a favoring climate, is responsible for the extensive deposits of peat which cover the eastern portion of the former bottom of glacial Lake Agassiz. The sandy soils of the old beach ridges and bars are practically valueless for agriculture, so much so that they remain largely uncleared in many areas. The heavier soils are generally of only moderate productivity for, formed from material deposited under water, they are often considerably leached. Further, even after artificial drainage they dry out slowly in the spring, thus delaying planting; in years of more than normal rainfall, the slow runoff of surface waters is often a serious handicap. The better sandy soils of the fossil deltas, which dry out and permit early planting, find occasional use for truck gardening where they are favorably located with reference to urban markets, as in some parts of Wayne County, Michigan, adjacent to Detroit.

Early occupation of the larger lacustrine plains, before artificial drainage was available, was often difficult. When the frost went out of the ground in the spring, roads on the clay became bottomless morasses, and almost impassable. For this reason, many of the early roads ran diagonally across section lines, along beach ridges, which were well drained because of their greater elevation and sandy soils. Farmers likewise located their houses and farmyards on these same ridges, if available, and similar sites were selected for the small villages. Even in a large urban center like Detroit, which is located on a lacustrine plain, many of the better residential sections of the city and its suburbs are on such sandy ridges, partly because of their slightly greater elevation and relief. The poor natural drainage makes it difficult to construct an adequate sewer system in Detroit. Wherever such a system is lacking, excavations fill with water during the spring, when the ground is saturated, and after heavy rains. Even where sewers have been installed, householders are sometimes subject to the annoyance of having water back up into basements. From the foregoing consideration, it is apparent that this type of land form, the lacustrine plain,

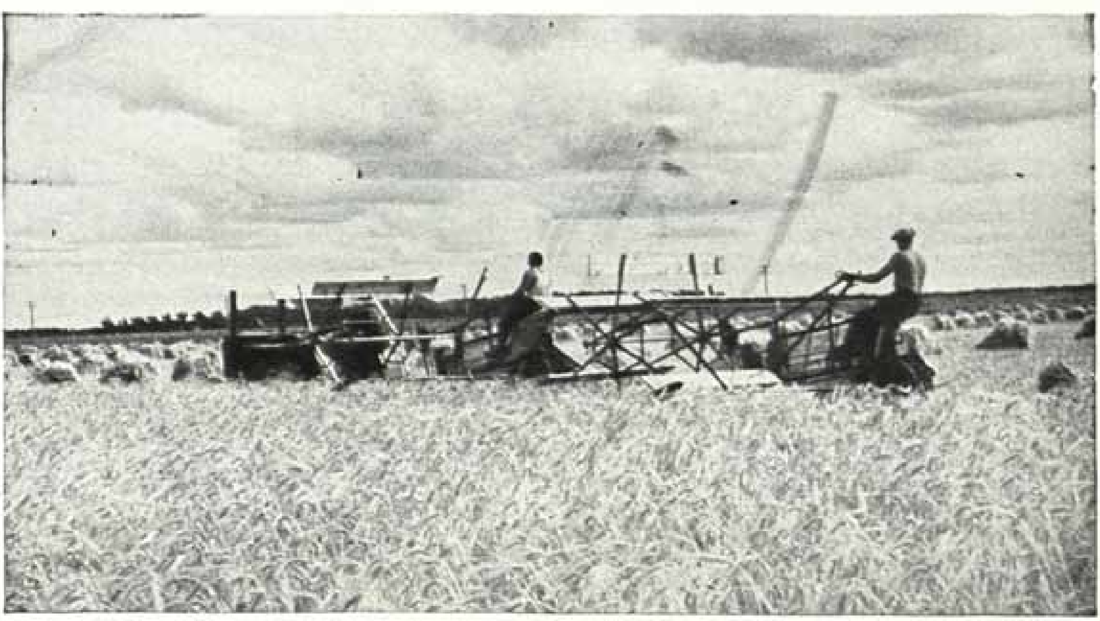

Fig. 190. Harvesting grain far out on the former bottom of glacial Lake Agassiz in the Portage Plain area, west of Winnipeg, southern Manitoba. The flat surface of the old lake bottom makes effective use of tractor hauled binders and other mechanized equipment possible. (Courtesy of the Canadian National Railways.)

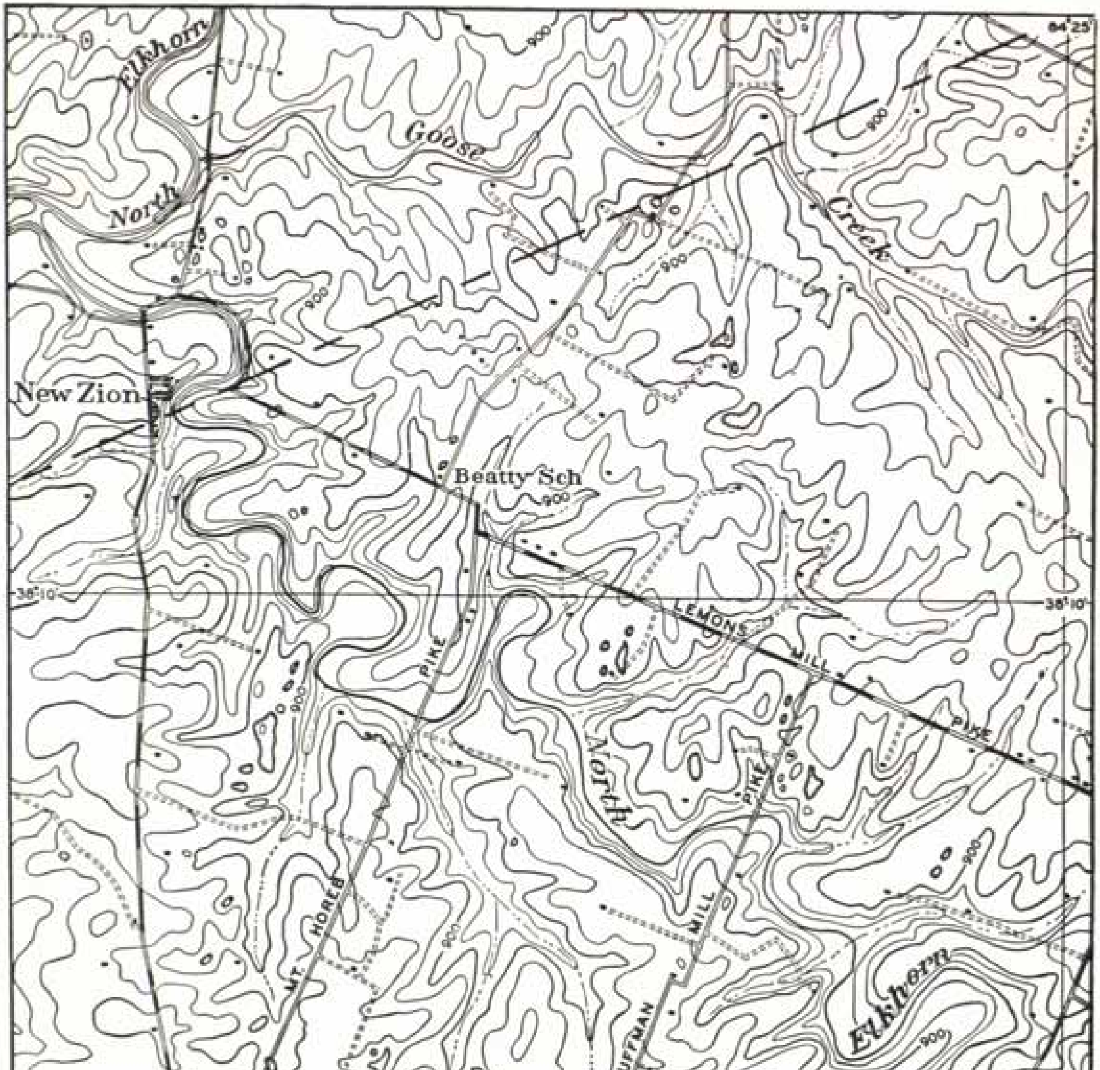

Fig. 191. Topography of the Inner Bluegrass, 7 miles south of Lexington, Kentucky. In this gently rolling area with productive chocolate-brown silt loam soils, much of the drainage is underground, and sink holes, in many of which water stands, are not infrequent. Only the larger rivers, which have cut below ground water level, flow at the surface, in gorges of some depth. Occupied before our present system of land survey came into use, roads do not follow section lines nor is their pattern affected materially by topographic conditions, their location reflecting convenience for users only. (After Lexington Quadrangle, Kentucky, U. S. Geological Survey.)

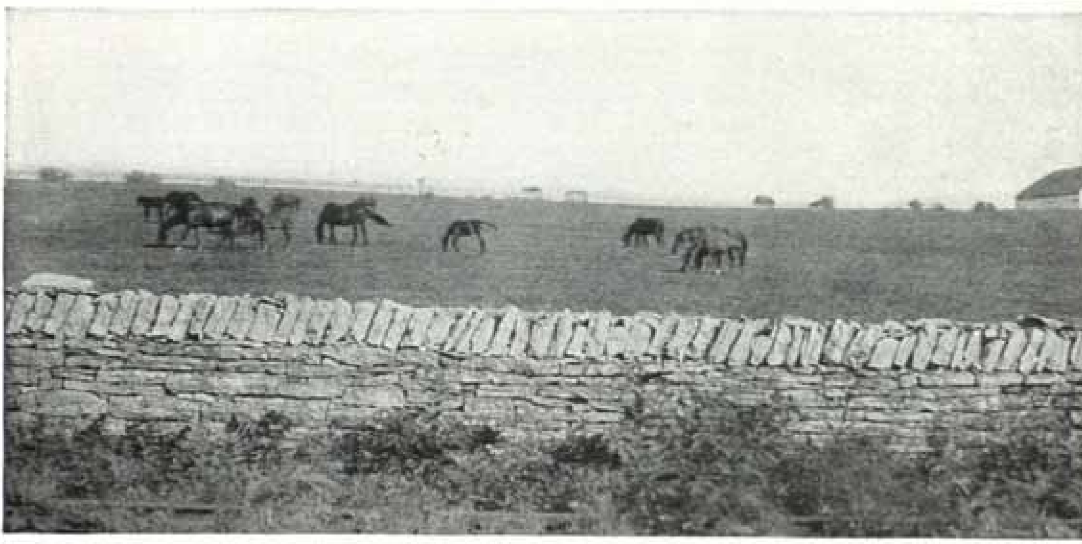

FIG. 192. *Top:* House at Great Crossing, Inner Bluegrass, Scott County, Kentucky. Typical of the better farm homes.
Bottom: Scene on the Paris Pike, Inner Bluegrass, 5 miles from Lexington, Fayette County, Kentucky. Typical limestone fence and stock farm.

affects both agricultural use of the land and the pattern of rural and urban occupation.

Degradational Plains. The four types of plains which have so far been considered are formed primarily by construction, either by crustal movement, deposition, or a combination of the two, with erosional processes accounting for only minor surface features. By contrast, the degradational plain is produced by erosional agencies, with others responsible for surface detail only. Such agencies produced the Bluegrass region of Kentucky which is, in its major aspect, a truncated dome underlain by gently inclined rock layers. Where present elevation and relief are largely the result of erosional processes, both topography and soils vary with the character and position of the underlying rock and the extent of degradation.

In the central part of the Bluegrass region, commonly known as the "Inner Bluegrass" because of its location, the underlying limestones

Fig. 193. *Top:* Typical farm and buildings on Taylor's Fork, Eden shale belt, Madison County, Kentucky. The road follows the creek; the steep slope back of the house is in corn and tobacco.
Bottom: A winding ridge road in the Eden shale belt, Pendleton County, Kentucky, 4 miles east of Falmouth.

weather into a gently rolling topography characterized by much subsurface drainage and numerous sinkholes, many of which hold water, commonly used for watering livestock. Soils, formed from residual material derived by disintegration of the underlying limestones, are chocolate-brown silt loams of high fertility. The environment, with favoring surface, soils, and climate, has permitted highly successful agriculture, with production of corn, tobacco, and hay, associated with an important livestock industry, particularly the breeding of fine horses. The superior opportunity of this area attracted attention at an early date, so that settlement began shortly after the American Revolution and occupation was practically complete by the close of the century. Compact in shape, of considerable size, and centrally located with reference to the Bluegrass region, both mathematically and as regards accessibility, for roads focus on Lexington, this subdivision of the Bluegrass is one of the most promising and highly developed areas of the South.

Surrounding this nuclear area is a circular belt of variable width, known as the "Eden shale belt" because of its shape and the fact that it is underlain by siliceous or sandy Eden shales. These weather into stiff yellow clays and a hilly topography, characterized by short, but generally steep slopes, which erode badly when deforested and used for growing corn and tobacco, the typical crops. Since settled early, and long

in agricultural use, erosion is today so serious that one is seldom out of sight of a field littered with slabs of shale; in many places the soil has been removed completely. Because of dissection, roads either follow creeks or wind for miles along the ridge tops. In either case, this increases distance of travel from place to place. Roads which do not accommodate themselves to topography are an uninterrupted succession of almost impossibly heavy grades and practically all, irrespective of location, are poor. This subdivision of the Bluegrass is handicapped by unfavorable topography, inferior soils, and poor roads, these limitations finding expression in poor living conditions.

Encircling the Eden shale belt in turn is the peripheral or marginal portion of the Bluegrass, a narrow circular belt only a few miles in width known as the "Outer Bluegrass." Underlain by limestones, like the Inner Bluegrass, the topography is gently rolling and the soils are productive silt loams. These favor the characteristic agricultural use of the land, Handicapped by extreme attenuation, however, and located between two areas of inferior opportunity: the Eden shale belt on its inner, and the equally poor Knobs area on its outer margin, this subdivision is less favored than the Inner Bluegrass, and this finds expression in the somewhat less attractive cultural landscape.

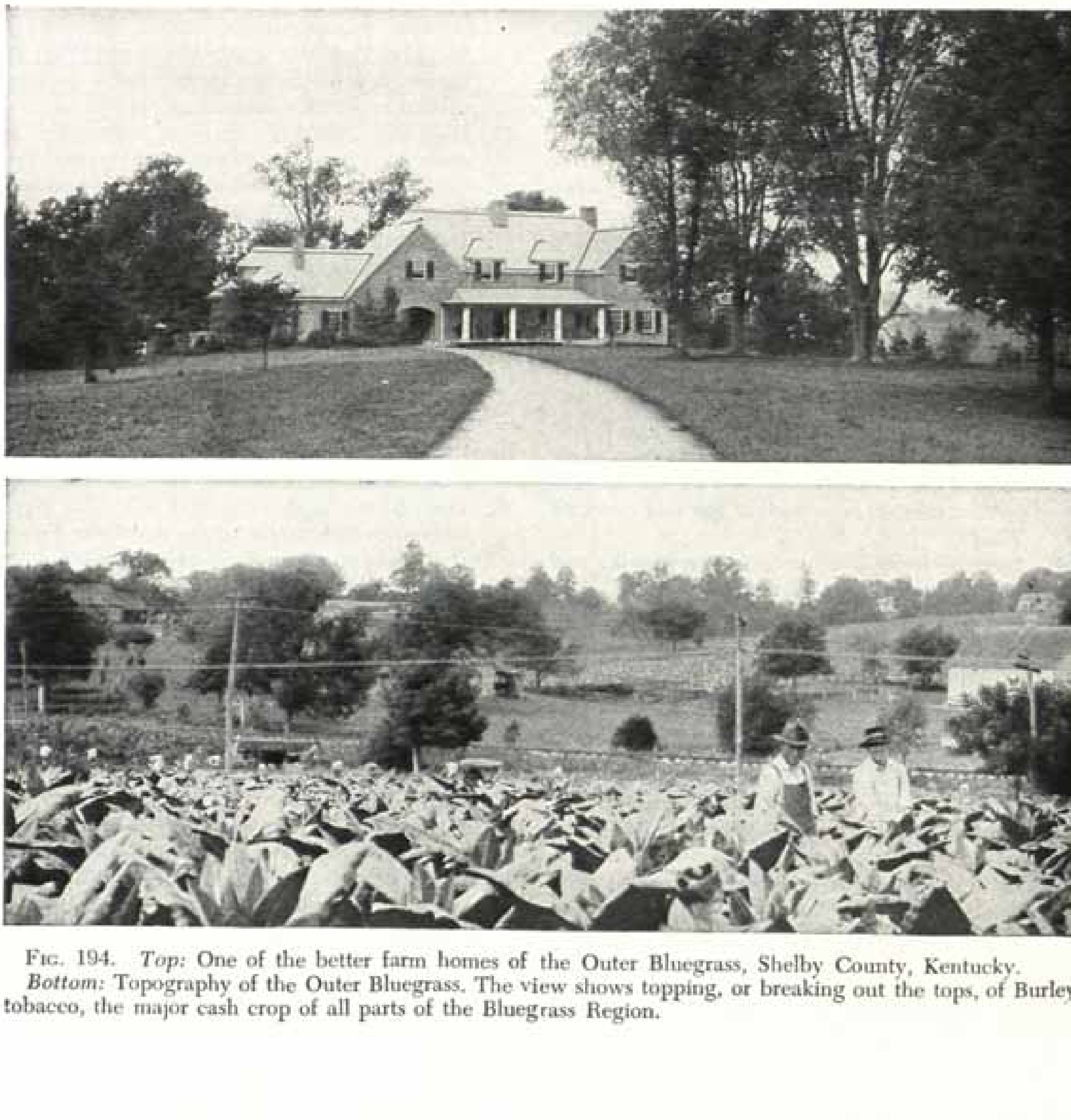

FIG. 194. *Top:* One of the better farm homes of the Outer Bluegrass, Shelby County, Kentucky. *Bottom:* Topography of the Outer Bluegrass. The view shows topping, or breaking out the tops, of Burley tobacco, the major cash crop of all parts of the Bluegrass Region.

From this description of a degradational plain, the Bluegrass region, it will be noted that degradational processes, working on different types of rock, produce varying surface forms and soils, with the pattern of their distribution determined by the position and location of the underlying rock exposed by erosion. In the Bluegrass this plan developed as a central nuclear area, the Inner Bluegrass, surrounded by two concentric belts: the Eden shale belt, and the narrow Outer Bluegrass. This arrangement resulted from truncation of a dome; elsewhere it will be different, if degradation of some other form of uplift occurs. Always, however, this pattern of topography and soils, which affects agricultural opportunity, will be repeated in the cultural landscape.

QUESTIONS AND EXERCISES

1. What is the distinction between highlands and lowlands? Name the types of lowlands. What is the basis for this subdivision?
2. How does population distribution indicate that plains present greater opportunity to man than do highlands? Under what conditions do population groups locate in highlands?
3. What is the origin of coastal plains? What is meant by the continental shelf? How much uplift of the ocean bottom would add its surface to that of the land it adjoins?
4. State the boundaries of the Atlantic and Gulf Coastal Plain of the United States. State some of the outstanding facts shown bv the topographic map, Fig. 177.
5. How is the hilly topography shown in Fig. 178 explained? Is this topography characteristic of all parts of the coastal plain of which this area is a part? Why are the soils of coastal plains commonly sandy?
6. Describe the drainage conditions and use of rivers in coastal plain regions.
7. Why is abandonment of land and return to forest common in many parts of the Atlantic Coastal Plain of the United States? To what special agricultural uses are some parts of this area devoted? Why?
8. Describe living conditions in the Atlantic and Gulf Coastal Plain of the United States.
9. Describe city development, its basis and handicaps, on the Atlantic and Gulf Coastal Plain of the United States.
10. How are alluvial plains formed? Describe the topography, soils, and drainage pattern of such plains. In what respects do the two alluvial plains shown in Fig. 181 differ?
11. Describe living conditions on undrained alluvial plains. Where is occupation concentrated in such areas? Why?
12. Discuss some of the problems confronting cities located on alluvial plains.
13. How are glacial plains formed? How is the poor natural drainage of glacial plains shown by the topographic map, Fig. 184?
14. From what handicaps does agriculture suffer in terminal moraine areas? On outwash plains? Under what conditions do terminal moraines afford good orchard sites? Where do outwash plains find use for truck gardening? Why?
15. In what respects do the natural conditions of till plains generally favor agriculture? What are the common handicaps to agricultural use often present in glacial plains areas?
16. How does present-day drainage in glacial plains areas differ from that of the preglacial period in the same area? Has this change been beneficial in any particular and, if so, how?
17. Has glaciation in general been beneficial or detrimental in glacial plains areas? Why? What is meant by the "Driftless Area"? Where is it located? How does it compare in desirability with adjacent glacial plains areas? Why?
18. What is the origin of lacustrine plains? How did the lacustrine plain of the Red River Valley originate? That of Aitken County, Minnesota?
19. Locate other important lacustrine plains in the Lake States.
20. Describe the topography and soils of a lacustrine plain such as that of the Red River Valley. How have topographic conditions affected the pattern of occupation shown in Fig. 189?
21. State some of the handicaps in agricultural use of lacustrine plains areas.
22. Name some large cities located on lacustrine plains. What problems are introduced by such a location?
23. How are degradational plains formed? Describe topographic conditions of the degradational plain shown by Fig. 191.
24. Why does the pattern of surface forms, soils, and economic activities of the Bluegrass region take the form it does: a nucleus surrounded by concentric belts? What determines this pattern of the subdivision?

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Davis, D. H., *Geography of the Bluegrass Region*, Kentucky Geological Survey, Frankfort, Kentucky, 1927.

This is a rather detailed study of the Bluegrass region.

Hobbs, W. H., *Earth Features and Their Meaning*, The Macmillan Company, New York, 1912, Chaps. XXII, XXIII.

This reference affords an interesting and readable account of the continental glaciers and the glacial lakes which marked the decline of the last ice age.

Tarr, R. S., and Martin, L., *College Physiography*, The Macmillan Company, New York, 1914, Chap. IX.

The chapter cited describes the extent of glaciation, types of glacial deposits, lakes marginal to the ice sheet during the close of glaciation, and the effects of glaciation on the present drainage pattern.

Chapter Twenty-Three

SURFACE FEATURES: HIGHLANDS

Highlands. Highlands, both plateaus and mountains, are of variable elevation. Some, like the low Ozark plateaus, for example, are of lesser elevation than high plains such as the Great Plains, though of greater elevation than the plains with which they have a common boundary. Again, an individual plateau may be either higher or lower than some mountain area, though any given plateau is normally lower than the mountains with which it is associated. Thus the distinction between plateaus and mountains, like that between highlands and lowlands, must be on some basis other than actual elevation.

In the following consideration of highlands, several types will be recognized, but no formal classification will be proposed because of the seeming impracticability of formulating one acceptable to all, or even most, geographers. Those considered include: (1) plateaus or "high plains," regions of considerable elevation without important dissection and therefore with extensive tracts where relief is slight; (2) dissected plateaus, uplifted portions of the earth's land surface underlain by horizontal or approximately horizontal rock layers, but mountainous in appearance as a result of extensive dissection; (3) glaciated uplands, regions of moderate elevation extensively denuded by ice action; and (4) mountains, areas of considerable to great elevation, in which the rock layers have been tilted or folded, either simply or complexly, and of marked relief.

These four subdivisions have certain common characteristics differentiating them from lowlands or plains. All have greater elevation and local relief than adjoining plains. Further, drainage is more rapid than in adjacent lowlands, and the generally lower temperatures and steeper slopes sometimes limit human occupation seriously. Again, communication is commonly more difficult, both internally and with outside areas, than in bordering regions of lesser elevation. In extreme cases, this may lead to great isolation and marked retardation, with preservation of customs and habits of life, often differing considerably in a given highland within short horizontal distances, but all long abandoned in adjacent lowlands. Because of climatic and scenic attraction, highlands as a class possess greater recreational possibilities than plains areas. In highlands, as well, the processes responsible for their formation, particularly in mountain areas, produce conditions favorable for concentration of metallic minerals in commercially exploitable deposits, so that mining of such deposits often assumes both great relative and actual importance.

In general, however, the characteristics which have been enumerated do not indicate great opportunity for man. Therefore highland areas, except those by relatively slight elevation which do not differ markedly from plains, are normally sparsely inhabited, with populations concentrated in definite, more favored portions. Further, as has been noted previously in connection with consideration of plains, such areas are the homes of sparser and weaker populations, forced into these less desirable parts of the earth's surface by stronger groups which have taken possession of the lowlands or plains, where opportunity is greater.

Low Plateaus. Lying to the west of the alluvial plain of the Mississippi River and to the east of the "Prairie Plains" is a series of low plateaus of varying degrees of dissection in southern Missouri, northern Arkansas, and a small portion of northeastern Oklahoma, with a total area of 40,000 square miles. This is known as the "Ozark region." In one of these plateaus, located in west-

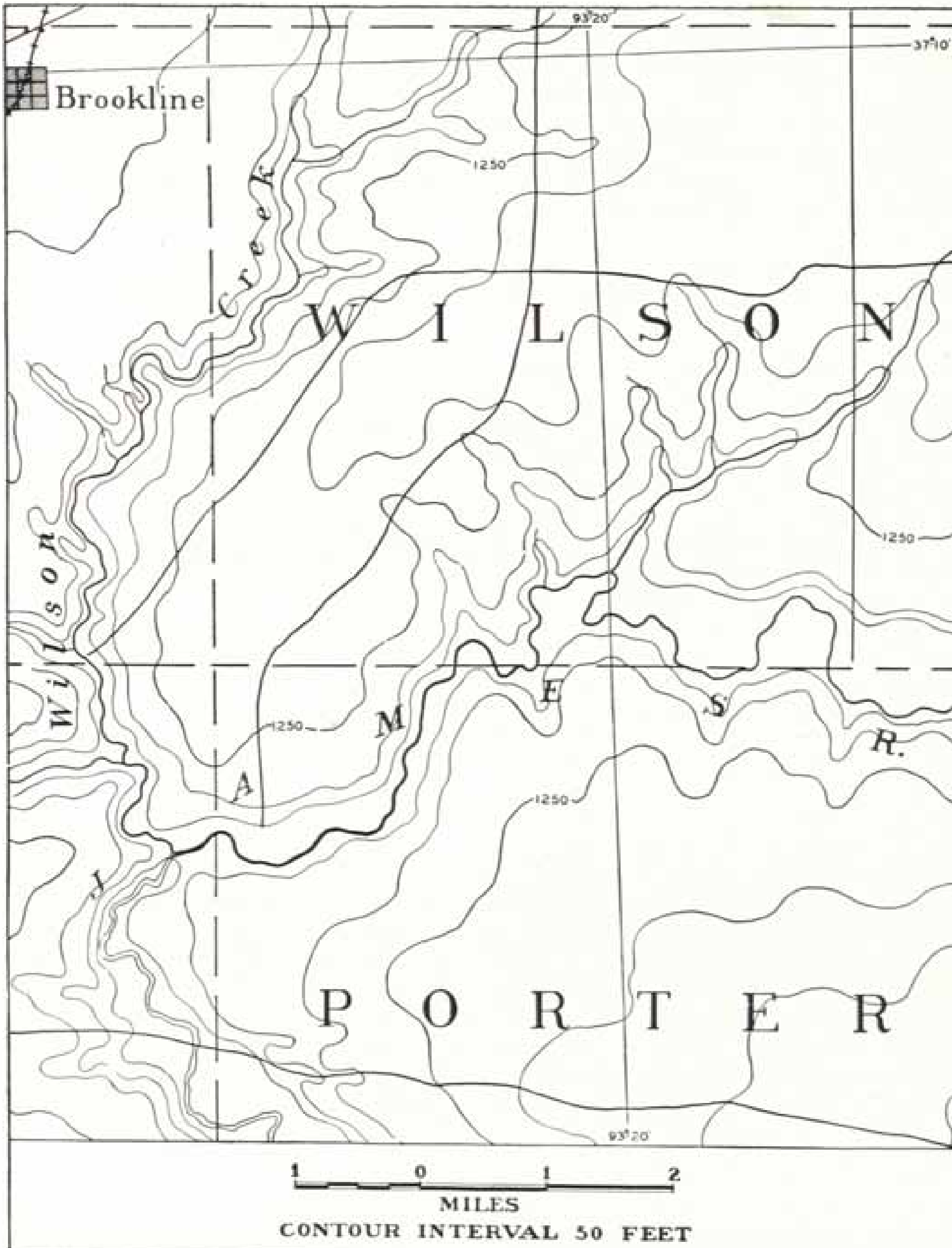


FIG. 195. Topography of a portion of the Springfield Plain, about 8 miles southwest of Springfield Missouri. The interstream areas are flat; only along the shallow valleys of Wilson Creek and its tributaries are slopes steep. Therefore roads, shown by single lines, are without heavy grades except as they cross the valleys. (After Springfield Quadrangle, Missouri, U. S. Geological Survey.)

ern Missouri, northwestern Arkansas, and northeastern Oklahoma, and known as the "Springfield Plain" after the Missouri city of the same name, dissection is so slight that surface conditions permit its classification as a "high plain" or plateau, as this term is used in this consideration of highlands.

This low plateau has an area of approximately 10,000 square miles and an elevation of 1200 to 1300 feet above sea level. It is undissected, except locally, and there to only a limited extent. Thus, as a whole, the Springfield Plain is monotonously flat, except for minor interruptions introduced by a few erosional remnants, sinkholes distributed linearly above subsurface drainage lines, and a few steep-sided but shallow valleys, developed subsequent to uplift. Since there are few streams of any size in this region, there are no valleys of great depth or width.

Soils are derived from cherty limestones by residual decay, with limited areas where they have been formed by disintegration and alteration of sandstones and shales. On the areally limited steeper slopes bordering the streams, they developed under a forest cover, but under prairie conditions on the flat interstream areas which make up most of the region. In this western border country of the Ozark plateaus, therefore, soils are fairly good, and much better than for the Ozarks as a whole.

Since most of the area is underlain by impure limestones, much of the drainage is underground. This is indicated by numerous sinkholes, in some of which water collects. From others, subsurface streams appear as large springs or, in them, surface streams may disappear to join underground drainage. In earlier days, the Springfield Plain was rather inaccessible and isolated, for the dissected country to its east made overland approach difficult, and large rivers, the highways of that period, do not penetrate this area.

As in many other highland regions, mineral wealth is an important asset in this plateau area, where zinc ores have long been mined in considerable quantity, and lead mining is likewise important. Nonmetallic minerals are also present and quarrying is an important industry, Carthage "marble" being the most widely used building stone in Missouri.

Settled relatively late by comparison with most parts of the Ozarks, because of its inaccessibility and grassland cover, important occupation began between 1820 and 1830. By 1823, Springfield, the "Queen City of the Ozarks," with a rapidly growing present population of approximately 60,000, had been founded on the margin of Kickapoo Prairie, one of the largest bodies of good land in the Ozarks. Though the first settlement was on the timbered margins of the prairies, where water, building material, and fuel were available, ease of road and rail construction soon led to occupation of most of the area and to its passage into profitable agricultural use.

In the counties of the Springfield Plain at present, from 78 to 87 per cent of the land surface is in farms, most of the land of which is improved and under cultivation. Farms are in general of moderate size, the average being about 98 acres, much smaller than in other parts of the Ozarks, where opportunity is less. Climate and land surface, in conjunction with good soils, permit profitable production of the major crops, corn and wheat. Of late, orchard and truck-garden production has met with considerable success. Such use indicates a highland of more than average opportunity. In other plateaus, promise and performance will vary with location, elevation, climate, soils, and other factors but, where elevations are considerable, plateaus, in common with other highlands, are areas of relatively low desirability by comparison with plains.

High Plateaus. In the "Colorado plateaus" of the southwestern United States, many in number and all with local names, a vast area of 130,000 square miles in Arizona, New Mexico, Utah, and Colorado, both the physical and cultural environments are quite different from those of the Ozark plateaus. This is because elevations, varying from one plateau to another, range from slightly less than 5000 to 11,000 feet or more. Occasionally these plateaus are even higher than near-by mountain ranges; all have much greater elevations than any of the Ozark plateaus.

Extensive areas of the Colorado plateaus are of only moderate relief, as in all plateaus where dissection has been relatively slight, except immediately bordering drainage lines. Even within a short distance from the brink of the Grand Canyon, therefore, only an apparently boundless "plain" stretches to the horizon. But, where streams have cut below this level surface, valleys are both steep-sided and often very deep. The pinnacled mazes of the Grand Canyon of the Colorado River in Arizona, over a mile in depth

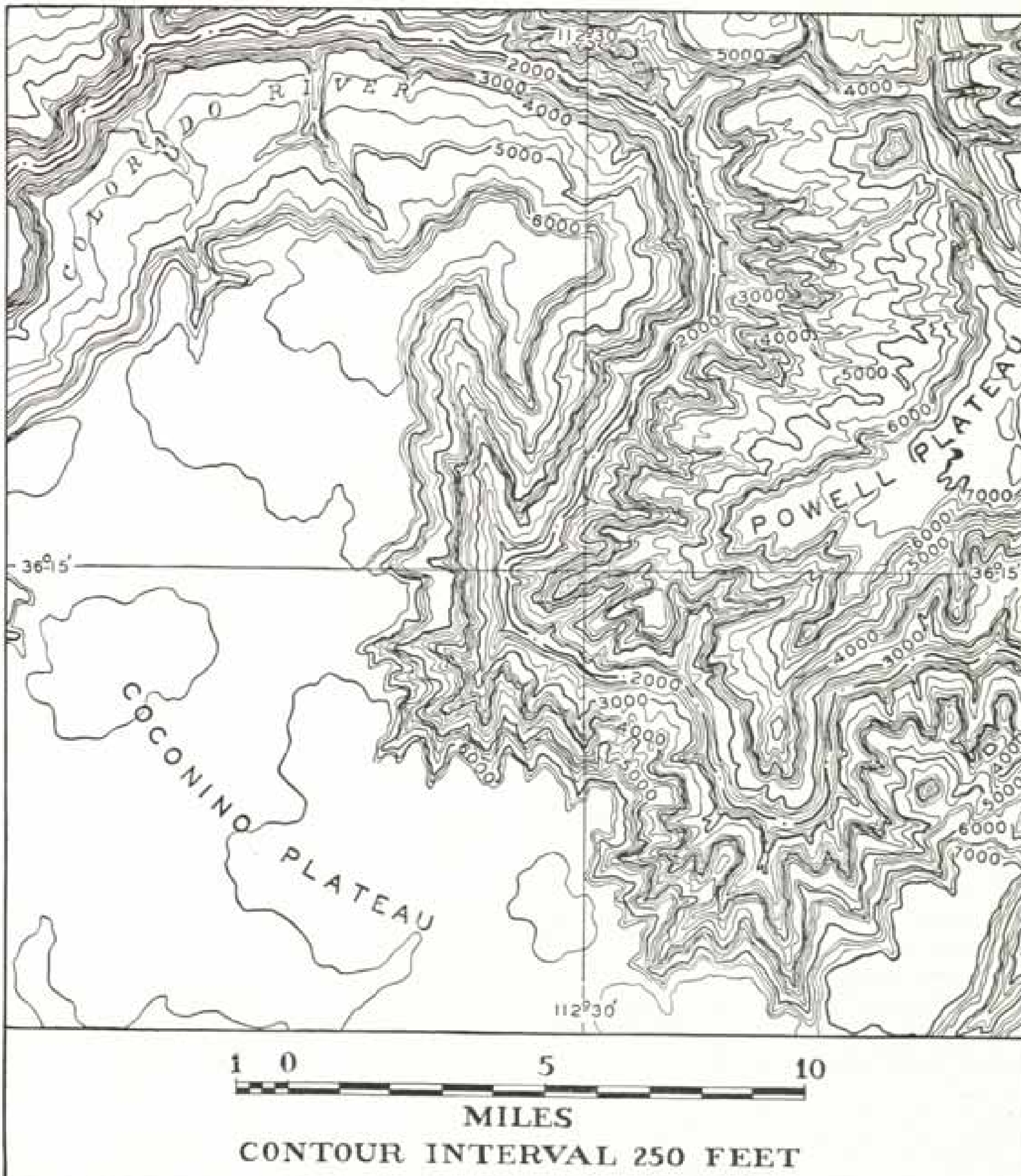


FIG. 196. Topography of a part of the Colorado plateaus to the southwest of the Kaibab division, with a section of the Grand Canyon of the Colorado River in the northwest, and the flat-topped surface of the Coconino Plateau in the southwest. To the east, a small erosional remnant known as the Powell Plateau is also shown. Note the considerable width and the great depth of the canyon at this point, and the fact that its northern brink is much farther from the river than the southern. This results from the fact that the heavier rainfall of the Kaibab Plateau, caused by greater elevation, produces more runoff and more rapid erosion. (After Kaibab Quadrangle, Arizona, U. S. Geological Survey.)

in places and bordered by vari-colored walls and fantastic erosional remnants, are one of the natural wonders of the world. Hundreds of other though smaller streams than the Colorado flow in similarly beautiful but less well-known and impressive multicolored trenches, far below the general level of the land surface. Because of this fact, all interpose obstacles of varying degrees of difficulty to airline travel.

In these lofty plateaus of the Southwest, largely cut off from moisture-bearing winds by topographic barriers, precipitation is generally light. In some places, in fact, the country is true desert, for the annual rainfall drops to 5 inches or less. This is not true everywhere in the Colorado plateaus, however, for in some places the precipitation is as much as 20 inches or more per year, and there desert gives way to park lands and forests, some of which would be of considerable commercial value except for their inaccessibility. The elevation of these plateaus, 5000 feet or more, is sufficiently great to affect both actual temperatures and the diurnal range. Cool to cold at night, it may be blisteringly hot in the sun in the middle of a summer day, though sensible temperatures are generally not intolerably high because of rapid evaporation in the dry air.

Because of lowered temperatures resulting from elevation, the considerable diurnal range of temperature, and the generally light rainfall of these high plateaus, many crops cannot be grown there successfully and agriculture tends to be limited to the subsistence type known as "floodwater farming," such as that practiced by the Hopi Indians. This type of crop production is described in some detail in a later chapter. Grazing, some seminomadic in type, and in the more favored areas, on a commercial basis, dominates the economy of much of this region, with mining assuming local importance wherever commercially exploitable occurrences of mineral wealth are present.

As a result of the scenic attraction of the great gorges the rivers have cut, the fantastic land forms, the beauty of the desert colors, the weird types of vegetation, and other factors such as the clear, dry air and the high percentage of sunshine, many are attracted to the southwestern plateaus as visitors and short-time residents. In the "Sunshine Country," therefore, dude ranches and other manifestations of the resort business have developed to cater to the demands of the vacation trade.

The characteristic economic activities of the Colorado plateaus, however, based as they are on unusual but not favorable combinations of topography and climate, indicate a general lack of opportunity for man. This is likewise suggested by the fact that much of the country is still in Indian occupation, the southeastern part of the plateaus being known as the "Navajo Country" because of its Indian inhabitants, the Navajos. Like all high plateaus, these support only a sparse population, certainly not equaling 1 per cent of that of the United States, though constituting nearly 5 per cent of its area. Similar conditions of population density are typical in comparable high plateaus in other parts of the world.

Dissected Plateaus. No sharp distinction between undissected and dissected plateaus is possible, because "dissected" is without quantitative value. In a typical undissected plateau, however, the major portion of the older, uplifted land surface persists without marked alteration; in a typical dissected plateau, stream action has converted the formerly flat surface of uplift into a maze of winding, narrow-topped ridges, separated by steep-sided valleys, with only a limited amount of flat land on their floors. Often the topography is so rugged that the region is mountainous in appearance and commonly referred to as a "mountain" area.

The Kentucky portion of the Cumberland Plateau, immediately west of the Appalachian Mountains and commonly known as the "Kentucky Mountains," affords an example of a plateau which has undergone extensive dissection. It is to the ridges of this area that the inhabitants and writers refer as "mountains," though there are actually only two mountains, Cumberland and Pine, and these are overtopped by some of the higher ridges of the dissected plateau proper. These ridges form a complex network except to the southeast, where Cumberland and Pine mountains parallel one another in a northeast-southwest direction, 10 to 12 miles part. Between these two true mountains are the so-called "Black Mountains," irregularly trending ridges and spurs, with summit elevations in excess of 4000 feet, produced by erosional processes in the essentially horizontal rock layers of the plateau. West of Pine Mountain, comparable but generally nameless ridges rise from 200 to 700 feet

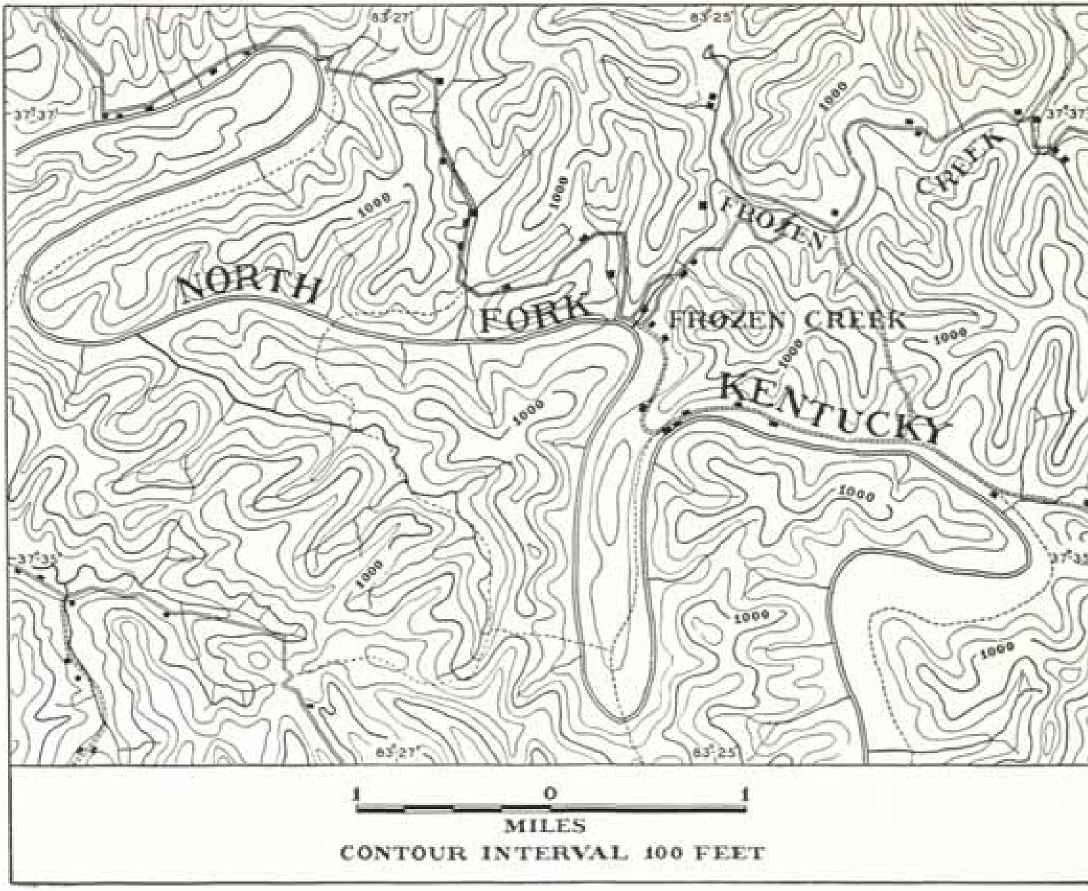


FIG. 197. Dissected plateau topography in the Kentucky Mountains, near Jackson, Breathitt County. In this area, dissection has been extensive. Roads follow the creeks; farms are confined to the small amount of land on the creek bottoms; ridge tops are much too narrow and their soils are too thin to permit occupation. Isolation is from valley to valley; in any given valley the farmhouses are rather close together. (After Salyerville Quadrangle, Kentucky, U. S. Geological Survey.)

above local drainage, decreasing in elevation from 2000 feet along the Tennessee boundary to 1000 feet at the Ohio River. Valleys vary in character with the type of underlying rock. On the western margin, castellated forms are numerous and sheer walls make travel from valley to valley across the intervening ridges almost impossible. Over the greater part of this dissected plateau, however, rivers and creeks are bordered by alluvial deposits of some width, from which the valley walls rise steeply but not precipitously.

Drainage is to the west, with the slope of the plateau, and stream pattern is mature, conforming to the degree of dissection. On the western margin, where the streams have cut through to underlying limestones, caves, sinks, and underground channels have developed, some of the smaller creeks which disappear underground being known locally as "sinking creeks." Access to the plateau from the east is difficult, for only one feasible break, the structural depression of Cumberland Gap and, a few miles to its west, Pine Gap, afford easy approach; from the west, penetration, by following up the valleys of westerly flowing streams such as the Licking, Kentucky, and Cumberland, is less difficult.

Early settlement of central Kentucky, the Bluegrass region, was in large part by an overland route through the Kentucky Mountains, by way of Cumberland and Pine gaps. Of the settlers headed for points to the west by this route, a few elected to remain in the mountains. Later, settle-

FIG. 198. Road up the valley of Quicksand Creek, Breathitt County, eastern Kentucky. The creek, which is large and at the right, swings against the valley wall at this point, forcing blasting of a roadway. The roadbed is solid coal, for a seam of coal outcrops at road level in the horizontal rock layers of the dissected plateau.

FIG. 199. The road goes over a "mountain" in Breathitt County, eastern Kentucky. This is a macadamized road, one of the better roads which are being built today. Note the steep slope in corn to the left of the road.

ment pushed in from the west, up the larger river valleys. Always, however, a difficult terrain has hampered movement into and within this dissected plateau, resulting in isolation of the population and preservation of speech, customs, and manners of life of a bygone day, in this "refuge area." Today, rail lines, entering by structural depressions or by way of the main drainage lines, have introduced material alteration in living conditions.

Most of the settlement is confined to creek and river bottoms, which determine the location of roads as well; in a few areas, where ridge tops widen sufficiently to permit limited settlement, roads wind along their level crests, except where they cross narrow, steep-sided valleys by heavy grades. Large families for several generations, and slight movement out of the area, have forced clearing of all level land and its use for growing corn, the principal and often the only food crop. Pressure on the land has been so great, in fact, that many of the rather steep slopes bordering the valleys have likewise been cleared and plowed, though their productive life under such use frequently does not exceed three or four years. Soil erosion, induced by this unwise practice, is serious throughout the mountains.

Concentration of a dense agricultural population in this region of limited opportunity has enforced low standards of living. Houses are commonly of log construction, with roofs of shakes or hand-split shingles. If built of lumber, they are small, unplastered, and ordinarily unpainted. Domestic conveniences are almost unknown. Houses are unscreened; water is obtained from springs or shallow wells; family washings are done out of doors, wherever water can be obtained from the deeper pools of the creeks and branches. With food inadequate in amount and limited in kind, malnutrition is widespread and its results are obvious.

Lumbering, a typical highland industry, was formerly important and some timber is still cut, but most of the forest wealth has been dissipated. Mineral wealth in the form of petroleum and coal has likewise afforded opportunity. Most of the oil has now been extracted, but the great reserve of highgrade bituminous coal still remains to form the basis for mining as an important occupation in those areas where rail construction permits exploitation. Scenic beauty, for the slopes are still attractive where not cleared and eroded, also plays a small part by drawing tourists and affording support for the permanent population, though not to the extent that the natural attractiveness of the area warrants. It will be noted that the economic activities of this highland area are those typical of highlands in general: (1) limited agriculture, (2) forest industries, (3) mining, and (4) the resort business, here of limited development.

FIG. 200. A steep slope in corn at the head of a small "cove" or valley. This is a complete farm, with all buildings shown. Perry County, Kentucky Mountains.

Other dissected plateaus resemble the Kentucky Mountains but, in detail, they differ considerably from one to another because of varying elevation, dissection, ease of access, mineral wealth, and other environmemtal aspects.

Glaciated Highlands. The great ice sheets which overrode North America during the Glacial periods denuded highland areas in which they originated and over which they spread, removing soil and other loose material. Movement of the ice also striated, or scratched, both the rock tools and the underlying strata; gouged out troughs in the bedrock; and even excavated linear basins in the softer layers between the more resistant strata, which today stand up as ridges. Loose material supplied in this manner was deposited to form the various topographic features of glacial plains discussed earlier; the highlands themselves were left nearly destitute or stripped bare of soil, except in a few depressions. Such has been the history of the glaciated upland which stretches west from Labrador, north of the St. Lawrence River, with minor extensions into the United States, one of which, the Arrowhead Country of northeastern Minesota, will be described as typical of glaciated uplands.

FIG. 201. A mountain home, Bell County, eastern Kentucky. The original one-room log house, with but a single door and no windows, is at the left; the unpainted, unplastered frame addition at the right, made of boards stripped with battens, is of more recent construction. The chimney is built of sandstone slabs, laid without mortar. The roof is of hand-split shingles. By contrast with the house, the highway on which it fronts, a portion of the old Wilderness Road, is an asphalt pavement, which indicates the change occurring in the Kentucky Mountains. Another typical mountain home is shown in Fig. 9.

Maximum elevations in this area reach 2230 feet, but the average does not exceed 1300 to 1400 feet. Therefore this is not a highland of great elevation, though on its eastern margin the land surface rises abruptly as much as 400 to 800 feet above the narrow lacustrine plain of glacial Lake Duluth. On attaining the general level of the upland, much of the surface is rather flat, with occasional ridges or "mountains" of hard, resistant rock, rising with steep or even vertical slopes to elevations of 400 feet or more above the bordering depressions carved in softer strata by ice action. Such depressions are often occupied by linear lakes with rocky shores and numerous islands, or they may accommodate drainage lines. This topography results from a long erosional history, with ice action responsible only for present minor surface irregularities.

The mineral soils are podzols; flat, poorly drained areas are covered by extensive and sometimes deep deposits of sphagnum peat, the swamps, in which the rivers head, imparting a brown color to the soft water of the streams. In most places, the mineral soils are thin, often to the extent that rock exposures occupy much of the surface. Where soils appear to exist, inspection will often disclose that they are frequently composed largely of organic material, so that they are destroyed by forest fires. Only in limited areas in depressions are soils of sufficient depth to tempt clearing for agriculture and, even there, they are generally stony; in some places to a degree that cultivation is virtually impossible. Almost everywhere, indeed, boulders must be removed from fields with every plowing.

Natural drainage is poor; on the flatter uplands, swamp conditions are common. Many of the depressions are occupied by lakes; in some areas, approximately half the surface is water, so that it is possible to travel many miles by canoe, with only short portages. Rivers flow in rocky gorges in their lower courses; on leaving the upland to descend to the Lake Superior level, all have one or more falls, in addition to others farther upstream. These characteristics of the rivers prevented use of most of them for running logs in the days when lumbering was important.

Originally, this glaciated upland supported a valuable coniferous forest, both on the better drained land and in the swamps. Today only a small fraction of this cover remains, and that in inaccessible areas, for it has been destroyed else-

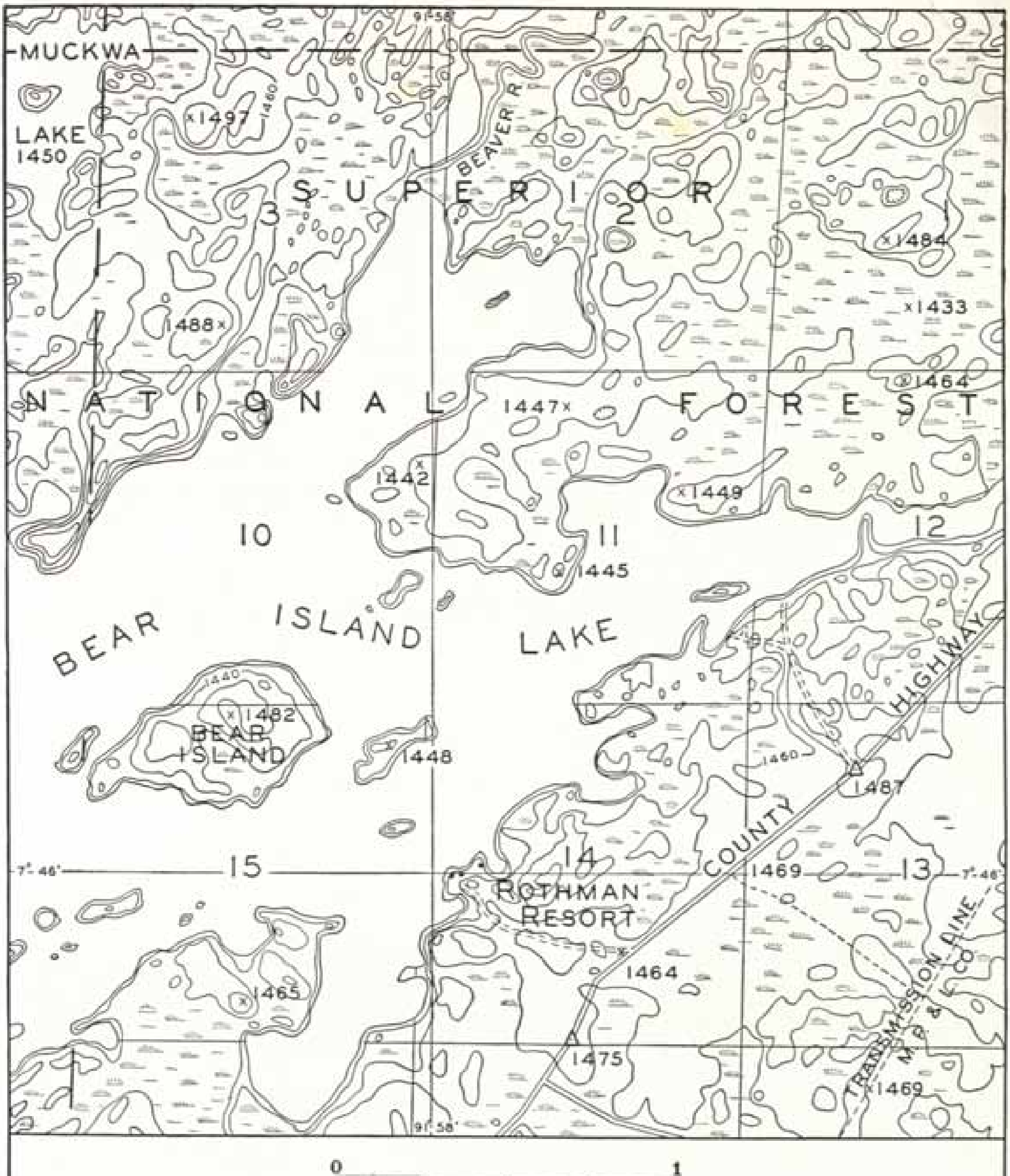


Fig. 202. Glaciated highland topography, 10 miles southwest of Ely, Minnesota, in the Superior National Forest. This portion of the highland is of slight relief, with lakes in the deeper depressions, and swamp conditions common throughout the flat, poorly drained area. There are no farms and, except for the one road which serves a resort of Bear Island Lake, no highways. Travel, except by water, is difficult, evidenced by errors in survey shown by section lines. (After Preliminary Ely Quadrangle, Minnesota, U.S. Geological Survey.)

where by reckless cutting and disastrous fires which accompanied and followed lumbering operations.

Much of the area is still difficult of access, except by water. Roads are few in number and often poor; in extensive areas, no rail lines penetrate, and none ever has, except logging roads, now all abandoned. During the long winter months, when the land surface is covered to considerable depths by snow; and during the spring, when the frost goes out of the ground, many of the roads are impassable and communication, both internal and with the outside, is difficult, away from a few main highways. Under this handicap, population remains sparse and largely concentrated along the main roads in the few areas where conditions, though poor, are better than average, particularly where mineral wealth or resort possibilities afford opportunity.

Population is supported by mining, forest industries, limited grazing and agriculture, supplementary fishing, and the resort business. The past geological history of the area has been such that one of the most important iron-ore deposits of the world, that of the Cuyuna, Mesabi, and Vermilion ranges, occurs in limited portions of this region. Locally, therefore, the area presents temporary opportunity and, where this is true, population is fairly dense and compact communities of some size exist. Originally the forest industry was important, but today the merchantable saw timber is virtually exhausted; cutting of pulpwood is practically all that remains; and this affords employment for only limited numbers. Agriculture likewise supports few, for climate, topography, soils, and location all conspire to prevent profitable production. The major crop is hay; the second, far less important, potatoes; the acreage of both is small. Limited grazing and fishing to supplement other income are occasionally possible, but such oppportunities are not generally available, and the number supported in this way is inconsiderable. In common with all highland areas, and more than for many, this glaciated upland affords recreational opportunity. It is a veritable canoeist's and sportsman's paradise. Miles of waterways, rivers and lakes, offer opportunity for both recreation and sport; fishing is good and game is abundant. The bracing summer climate is likewise an attraction, plus the beauty of the rivers and lakes, drawing many to the Arrowhead Country each summer.

Taking all natural advantages into consideration, this highland area is one of limited opportunity, except in restricted tracts where mineral deposits occur. Forest wealth is exhausted; agriculture is generally unprofitable; isolation is often considerable. These unfavorable conditions are

FIG. 203. A typical scene in the glaciated upland of Lake County, northeastern Minnesota. In the background, is the "mountain" of more resistant rock; in the linear depression in the foreground is Lax Lake. Soils, though stony, as may be seen in the field in the foreground, are of sufficient thickness here to have tempted clearing and attempted agricultural use. Along the lakeshore, hidden by trees, are about 40 cottages, for the resort asset, here as elsewhere in this glaciated upland, is more important than agriculture.

FIG. 204. This load of white pine logs is destined for the Cloquet mills, nearly 200 miles distant. Such trucking, made necessary by lack of rail lines, is expensive, preventing marketing of all except the best sawlogs.

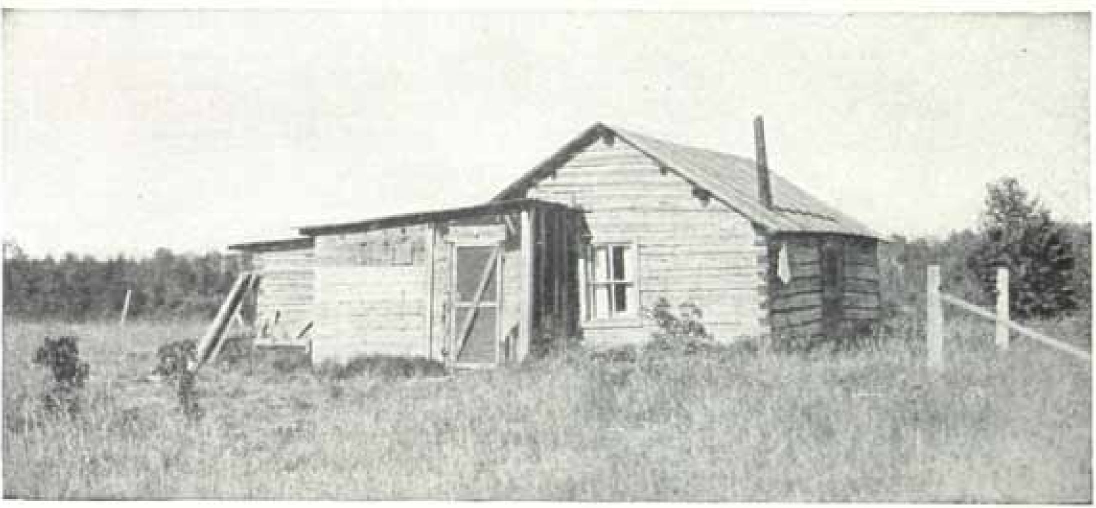


FIG. 205. An abandoned farm in Lake County, northeastern Minnesota. This farm of 30 acres of cleared land was abandoned in 1933 and, though for sale for $75, is still unoccupied. Increasing abandonment of farms in this area, and accompanying tax delinquency, have raised taxes to the extent that they commonly equal 6 per cent of a true sales value.

not and cannot be offset completely by scenic beauty and recreational values. The result is that tax delinquency and land abandonment, especially off the main highways, have assumed serious proportions, virtually bankrupting many of the counties. The land is, therefore, gradually but surely passing into state and national forest ownership. Already, all of Cook County, the easternmost of the area, lies completely within the boundaries of such forests or in Indian Reservation, and the same fate awaits many other portions of this glaciated highland in the near future. This is, in itself, an indication that the area lacks opportunity, use for a forest crop yielding low returns and being desirable only in case land is unsuited for some other more profitable use.

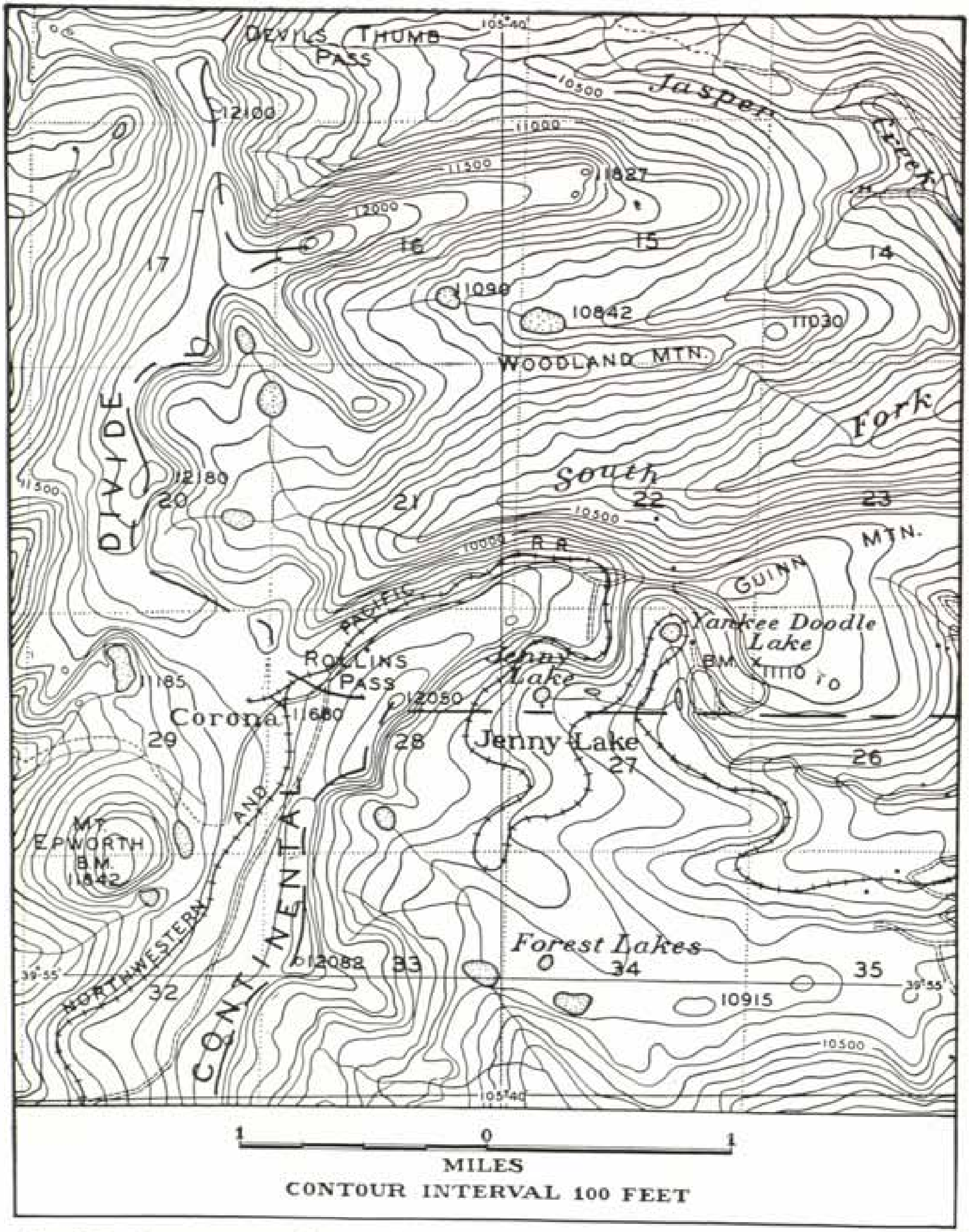


Fig. 206. Mountain topography in northwestern Colorado, about 30 miles northwest of Denver. Summit elevations exceed 12,000 feet and relief is great. Roads and rail lines follow valleys, crossing the Continental Divide by way of gaps or "passes", where elevations are lowest. The circuitous routes of the rail line and of the main east-west highway, on either side of Rollins Pass at an elevation of 11,680 feet, evidence the handicap topography imposes on transportation. (After Central City Quadrangle, U. S. Geological Survey.)

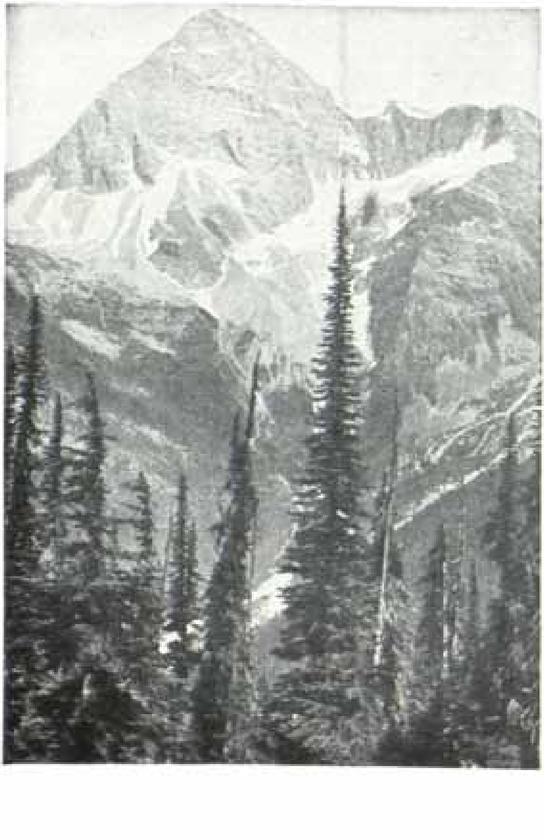
Mountains. Mountains are the result of crustal deformation which produces elevation, accompanied by tilting or folding of the strata, either simple or complex, and often great alteration of the rock layers. Generally marginal to ocean basins, mountains are sometimes of great elevation, a major uplift of the land surface being matched by a corresponding depression of the ocean floor, or a "deep." The Tuscarora Deep, of 4655 fathoms or 5½ miles, off the coast of Japan is a depression of this type.

Though the general pattern of mountain distribution results from concentration of uplift in definite areas along lines of weakness which border the great ocean basins, the detailed surface features of each mountain area are the result of erosional processes and, sometimes, volcanic activity, which is often associated with mountain formation. This is because of the fact that, no sooner does uplift begin than running water, ice, and other agents of erosion operate to lower the surface differentially, thus producing mountain "peaks" such as the Matterhorn of Switzerland or, again, volcanic activity may build a great cone like that of Fuji, which rises 12,395 feet above sea level at the landward end of the peninsula of the same name in Japan. Only so long as mountain uplift continues actively do mountains increase in height; with its cessation, erosion eventually reduces the uplifted area to one of both slight elevation and relief. Thus both very young and very old mountains are of relatively slight elevation; only during late youth and early maturity do they rise to considerable heights above sea level.

Mountain uplifts of considerable elevation modify the general climate of areas distant from them and also cause local variations, related to configuration, within the mountain region itself. These local variations result from differences in elevation and the amounts of heat received by slopes of different exposure and valley floors. At sufficient elevations, varying with latitude, temperatures may be so low that snow covers the ground at all seasons of the year, even at the equator. Not only does temperature decrease with elevation, but the air also becomes thinner, so that normal breathing does not supply sufficient oxygen to make severe physical exertion possible for persons accustomed to living at or near sea level. The normal vertical distribution of temperature, which introduces zoning of native vegetation and cultivated crops, is interrupted locally by differences in exposure. Thus a sunlit slope is more desirable than one of the same elevation facing in such a direction that it is shaded much of the time, or that it receives only rays of the sun which strike very obliquely and therefore have but slight heating power. Sunlit slopes may even be more desirable than shaded valley floors; the latter may also suffer from lower temperatures caused by drainage of cold air from bordering slopes. These local differences may be sufficient to obscure in considerable part the effects of temperature decrease associated with

Fig. 207. A heavy grade on the Canadian Pacific Railroad, near Field, British Columbia. Following up the valley of a small stream, a tributary of the Bow River, the train is about to enter a spiral tunnel through the ridge dividing the drainage basins of the Bow and Columbia rivers. Note the two locomotives necessary to pull the train. In the background is Mt. Stephen, one of the majestic peaks of the Canadian Selkirks. (Courtesy of the Canadian Pacific Railroad.)

FIG. 208. Lake Louise, one of the beauty spots of the Canadian Selkirks. Its linear basin, formed by glacial action, and bordered by precipitous, tree-clad slopes, is filled with blue-green water supplied by melting glacial ice. This lake is typical of many of similar origin throughout this area. (Courtesy of the Canadian Pacific Railroad.)



elevation. Local topographic conditions within a given mountain area likewise affect the amount of precipitation, neighboring slopes often receiving quite different amounts, varying with their relationship to the direction of the prevailing winds. Thus the windward or western slopes of the Sierras receive 50 or more inches of rainfall, as the warm, moisture-laden air expands and is cooled in rising over the barrier. Once over the summit elevations, the air descends and, on descending, is compressed by the weight of the overlying air and thereby warmed, so that its capacity for holding moisture increases and rainfall is light, generally less than 5 inches in the Great Basin region in the "rain shadow" of the Sierras. Within mountain areas everywhere these same differences in precipitation may be noted: windward slopes being relatively well watered and sometimes forested; lee slopes, where the

FIG. 209. A scene in the Canadian Selkirks, which offer some of the grandest mountain scenery in the world. At the left, in the background, is the pyramidal mass of Mount Sir Donald; at the right, a glacier issuing from its "cirque" or collecting basin; in the foreground is a mountain valley with its ice-fed stream. (Courtesy of the Canadian Pacific Railroad.)

FIG. 210. Crater Lake, Oregon, easily accessible from Medford by an excellent road. From 5 to 6 miles in diameter, the lake is nearly 2000 feet deep, with shores which rise steeply from 900 to 2200 feet above its blue waters. This depression is a caldera, or the crater of an extinct volcano, in which Wizard Island at the right is a small cone built subsequent to extinction of the great volcano in the crater of which the lake now occurs. (Courtesy of the U. S. Department of the Interior.)

capacity of the air for holding water is increasing, being drier and often desertlike in character.

In the tropics, a relatively slight elevation improves conditions materially from the standpoint of man. For example, at an elevation of 6000 feet the average temperature may be 70° F. and daily range considerable, whereas adjacent lowlands near sea level swelter at 90° F., with but small change from day to night, often associated with high humidity. Thus temperature conditions of the Andean plateaus are much better than those of the Amazonian lowlands, and Quito and La Paz, at elevations of 9000 feet or more, are healthful, whereas the near-by lowlands are hot and disease-ridden. It should not be understood, however, that the lower temperatures of tropical highlands ensure a climate similar to that of higher latitudes with comparable temperatures. Moreover, in higher intermediate latitudes, even minor elevations may produce decrease in opportunity or, in some cases, cause an area to be uninhabitable.

In mountain regions, roads and rail lines follow natural depressions or valleys, crossing divides at low spots in the ridges separating drainage basins. Generally circuitous, thus increasing distances and costs of transportation, grades of these roads and railroads are heavy on either side of the passes. This decreases the load possible, slows traffic, and increases the cost of moving freight. Sparse population and lack of sufficient freight to be moved often make adequate road and rail construction economically impossible, causing dependence in part upon primitive transportation by pack animals. This likewise hampers development.

Mountains affect distribution of population and pattern and type of land use, both vertical and horizontal, because topography restricts effective occupation to limited areas and vertical temperature gradients, plus temperature and precipitation variations related to exposure, cause marked differences in opportunity. Vertically, this differentiation in opportunity in mountains

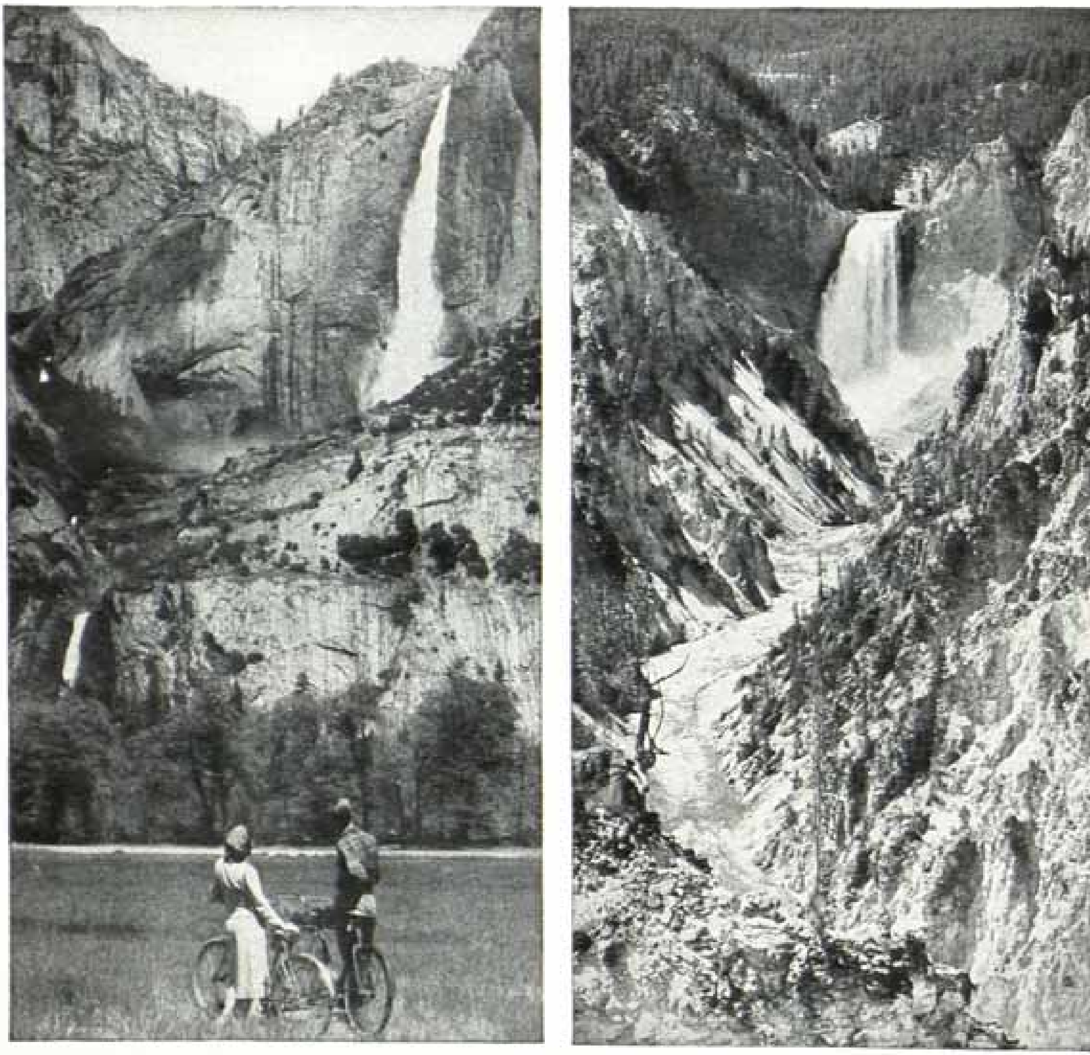


FIG. 211. *Left:* Yosemite Falls, Yosemite National Park, California. The Yosemite Valley is 4000 feet above sea level, 7 miles in length and from ½ to 1 mile in width. It is generally assumed to be of glacial origin: a great trough carved by ice action. Several streams, flowing over the cliffs which border it, develop falls, one of the most remarkable being Yosemite Falls, 2600 feet in height. This spectacular valley, with its sheer walls, is visited each year by thousands of persons attracted by its scenic beauty. (Courtesy of the U. S. Department of the Interior.)

Right: Lower Falls and Grand Canyon of the Yellowstone River, Yellowstone National Park. The Falls are caused by a resistant rock layer which crosses the river. Erosion downstream from the resistant layer is rapid. This has produced the canyon with its varicolored walls; bright orange, yellow, red, and purple. In all, this canyon is 24 miles long and from 600 to 1200 feet deep. Upstream and at the Falls, erosion is checked by the hard ledge over which the water drops 308 feet as a solid sheet to produce one of the most beautiful sights in this country. This spot is visited each summer by thousands of tourists, for whom the Park Service provides excellent accommodations of various types. (Courtesy of the U. S. Department of the Interior.)

is somewhat the equivalent of the horizontal over extensive plains areas. Thus, whereas the population of plains tends to be distributed uniformly, except for urban concentration, by contrast, rugged mountain surfaces confine most of the inhabitants to a few favored spots. Therefore major agglomerations are along the main river valleys served by highways, and important urban aggregations are located at the foci of these same lines of travel and transportation. Except locally, and in small areas, relatively limited potentialities make mountain regions inferior in the opportunity they afford.

In the lower latitudes, except for escape from lowlands during the hot season, as from Delhi to Simla in India, there is but little or none of the seasonal vertical shift of activities made necessary in higher latitudes by annual ranges of temperature which prohibit winter use of the higher slopes. During the warmer months of high latitudes, however, various economic activities may be carried on coincidentally by the same population group at different levels, much as nearer the equator throughout the year: crop production in valleys at lower elevations; grazing of flocks and herds, and manufacture of dairy products on summer pastures of higher, ice-free slopes. This distribution of economic activities is characteristic in the Swiss Alps.

Mountains, in common with other highlands, afford recreational possibilities and, because of their greater elevation and relief, in greater degree than average. This explains, in part, why so many of our national parks are in mountain regions. Though such areas enjoy greater popularity during the summer, winter sports have of late attracted increasing numbers.

Mountains not only affect populations which live within their borders, but they may also either protect or handicap other groups outside their limits, for they always obstruct movement. The ranges of the Himalayas, for example, have always prevented invasion of India from the north; only from the northwest, where the mountains break down and comparatively low passes exist, is it possible to enter the Indo-Gangetic Depression without great difficulty. Hence all invasions of the past have come from this direction. Similarly, the fact that Africa is often said to begin at the Pyrenees indicates the comparative importance of the Pyrenees and the Strait of Gibraltar as barriers, and emphasizes the importance of the mountains. Whether a given mountain barrier is effective depends on its height, its width, and the number and elevation of its passes. The Himalayas are effective, for they are high, and their passes are both few in number and at great elevations. Hence this barrier has played an important part in the life of the population and in the history of India.

QUESTIONS AND EXERCISES

1. Name the subdivisions of highlands and state their common characteristics.
2. What relation does the Springfield Plain bear to the Ozark region? How does it differ from many other parts of this region?
3. Describe the topography, soils, and drainage of the Springfield Plain.
4. Why was the Springfield Plain settled relatively late? What is the character of the present occupation of the area?
5. How does the Springfield Plain compare in desirability with other parts of the Ozarks? Why?
6. What are the surface elevations of the part of the Colorado plateaus shown by Fig. 196? How do these compare with those of the Springfield Plain, Fig. 195?
7. What is the character of the river valleys of the Colorado plateaus? How do such valleys affect the accessibility of the area? Why?
8. Why is the precipitation of the Colorado plateaus generally light, but variable in amount from place to place? Between what limits does it vary? How does this variation affect the types of vegetation?
9. Name the economic activities of the Colorado plateaus. How are they affected by topographic and climatic conditions? What is meant by "floodwater farming"?
10. State some facts which indicate that high plateaus such as those of southwestern United States are areas of limited opportunity for man.
11. How large a population do the Colorado plateaus support? What is the character of this population? Why is so much of their area Indian country? What Indian tribes make their homes in this area?
12. What is the distinction between dissected and undissected plateaus?
13. Describe the elevation, topography, and drainage of the Kentucky Mountains, a dissected plateau.

14. Describe the settlement of the Kentucky Mountains. To what areas is human occupation confined? Why?
15. Discuss living conditions and the economic activities of the Kentucky Mountains, both past and present.
16. Where did the great ice sheets of the Glacial periods originate? What areas did they cover in North America?
17. Why is there so little soil in glaciated uplands? What is the character of the soil in such areas?
18. Describe the drainage of glaciated uplands.
19. What economic activities serve to support man in glaciated uplands? Why is agriculture relatively unimportant in such areas? What are typical crops?
20. What mineral resource is important in the glaciated upland of northeastern Minnesota? In what "ranges" does it occur?
21. What are the best uses for the larger part of glaciated uplands?
22. How are mountains formed? In what fundamental respects do they differ from plateaus?
23. What is a "deep"? What relationship does it bear to a mountain uplift?
24. Why may a sunlit slope in a mountain area be preferable to the flatter land of a valley floor for agricultural use? Why may the agricultural desirability of areas vary greatly within short distances in mountain regions?
25. Why is physical exertion difficult at great elevations?
26. Compare and explain the difference in precipitation on the west slopes of the Sierras and in the Great Basin to their east. What is meant by the term "rain shadow"?
27. Describe the pattern of population, including urban location, in mountain areas. What is the basis for this pattern?
28. What determines the effectiveness of a mountain barrier? Name some effective mountain barriers. Why are the Himalayas so effective as a barrier?

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A rather detailed description of the Kentucky Mountains and the living conditions and economic activities of their inhabitants.

Peattie, R., *College Geography*, Ginn and Company, Boston, 1926, Chap. XII.

This chapter affords a description of mountaineers, their economic activities, and a simplified consideration of mountains.

Tarr, R. S., and Martin, L., *College Physiography*. The Macmillan Company, New York, 1914, Chaps. XIV, XV.

These two chapters treat of plains, plateaus, and mountains from the point of view of the physiographer.

Chapter Twenty-Four

MINERALS

Early Man and Minerals. Man's first use of minerals long antedates the period of written history. The story of their earliest use must, in fact, be deciphered from the record left in gravels and other deposits of the time when human beings shared the earth with the mammoth and the wooly-haired rhinoceros, for the earliest known tools and weapons made by man are found buried with the bones of these animals.

These earliest implements were generally made of flint, which occurs as nodules of high purity in certain beds of chalk but, where flint was not available, other minerals such as chert, obsidian, chalcedony, and quartzite were sometimes used. Many of the first "flints," or stone tools made by man during this very early or Paleolithic period, were so crude that they closely resemble the flakes produced by natural agencies such as frost action.

Somewhat later, during the Neolithic period, though still long before the time of written history, these stone implements were improved by secondary flaking, grinding, polishing, and piercing. Manufacture was slow; polishing was by rubbing on stone; drilling was by hand, with use of abrasive sands. A man might spend the leisure of a lifetime in perfecting one tool, and not a very good one at that. Implements by this time also assumed a greater variety of forms and a greater degree of specialization, so that their exact uses are easily recognizable, not always possible with the earliest flints of the Paleolithic period. In many cases, indeed, they were superior to those made by primitive populations of recent times. Such were the tools and weapons of man during the Stone Age, when his dependence on minerals was limited to use of nonmetallic flint or some other mineral with a similar fracture, which permitted chipping.

These Neolithic implements are often found on the surface of the ground or just under it, as well as somewhat more deeply buried on the former sites of dwellings and in tumuli or burial mounds. Though relatively common, being frequently uncovered by plowing or excavation, their origin and significance were long unknown. For example, in Scotland the stone hammers were popularly known as "Purgatory Hammers," supposed to have been buried with the dead to enable them "to knock at the doors of Purgatory until the heavenly janitor appeared"; the arrows were thought to be "elf darts used by the fairies."

Bronze and Its Early Use by Man. Early man probably knew copper and its property of malleability, which fitted it for easy shaping, long before he discarded the use of stone implements, for it occurs pure in nature. Nevertheless, he made only slight use of this knowledge because the softness of the metal made it unsuited for most of his needs. At some unknown but relatively recent time, however, he discovered, probably accidentally, that if alloyed with tin it became harder and could be cast. Further, this alloy of copper and tin, or bronze, possessed the advantage that, if made into a cutting tool such as an axe, it could be hammered cold and thus sharpened if it became dulled in use. Exactly where man first acquired this knowledge of bronze is uncertain, though it is known that its use, introduced into Europe from some other area, was common in that continent from about 2000 B.C. to 800 B.C., a period sometimes known as the "Bronze Age."

Because bronze requires both copper and tin, metals which are not found everywhere, and in few places close together, its manufacture and use must have been restricted to very limited areas, as long as man was dependent entirely on

local resources to satisfy all his needs. A rudimentary commerce must therefore be assumed before use of bronze became general and widespread. This serves to illustrate how exchange of commodities and ideas makes for progress and raises standards of living.

Early Use of Iron by Man. Of all the valuable metals of the earth's crust, the cheapest, and next to aluminum the most abundant, is iron. Fortunately, it is also the most useful of them all and perhaps the most indispensable of all substances used by man, except the air he breathes, the water he drinks, and the food he eats. Iron owes its importance in part to its abundance and wide distribution but, in even greater degree, to its varied values and properties. Thus it is hard in files, soft in horseshoe nails; brittle when cast, malleable and ductile when wrought; springy, or without resilience; and magnetic or nonmagnetic. It is the "Proteus of metals." This is why it has no adequate substitute.

When and where iron first attracted the attention of man will never be known, though this probably occurred when its ore was accidentally heated in some prehistoric wood fire, with the result that a black mass of the metal was later found in the ashes. Certain it is that manufacture of iron, even by semisavage tribes, has been widely distributed for ages and that there has been no civilization with a written record that has not made some use of the metal. Some believe that knowledge of iron and its use extends back to 4000 B.C. in Egypt, Assyria, and China, but this is not certain.

In Egypt, though known, rare, and valuable, it was apparently considered "impure," since it was not used for religious purposes. The early Hebrews were certainly acquainted with iron, for Tubal-cain, of the seventh generation after Adam, is described in Genesis iv:22 as "an instructor of every artificer in brass and iron." It was apparently rare and costly among the Jews, as elsewhere. Thus the iron bed of Og, king of Bashan, mentioned in Deuteronomy iii:11, was obviously considered equally as valuable and unusual as the couches of pure gold, which were not unknown among the princes of that time. The early Greeks likewise knew iron as rare and precious, for it is noted that Alexander "took plunder of iron" in India. It was also familiar to the Romans and likewise to the Carthaginians, who used steel swords of Spanish manufacture in the battle of Cannae in 216 B.C. By, or even before the Roman conquest, its use had spread to the British Isles and throughout much of northwestern Europe. Despite this widespread knowledge of the metal, it remained scarce and high in price, for smelting methods were crude and did not improve materially for hundreds of years, or until invention of the modern blast furnace about 1340 A.D. It should not be inferred, however, that iron secured by the early methods was poor, or that it did not make good steels. Witness the celebrated Damascus blades as evidence to the contrary.

Wrought iron, the first kind obtained, is both relatively soft and malleable, which fits it for only limited use. For many purposes, indeed, hard bronze is superior. Therefore iron did not come into its own and the Iron Age become a reality until steel, nearly pure iron made by fusion processes and having various properties dependent on the percentage of carbon remaining, was known. Therefore the important question is: who were the originators of steel, which has made modern Western civilization possible? This question is likewise impossible of certain answer, partly because early steel workers, popularly regarded as sorcerers in league with evil spirits, a belief encouraged by the workers themselves, guarded both the processes and the history of manufacture. Even as learned a man as Pliny did not know its history, though he knew many makers of steel.

The oldest direct information known concerning its employment and working is found in I Samuel xiii:22, where shares, coulters, axes, mattocks, and files are mentioned; by inference, of steel. Similarly, the scythes attached to the axles of the war chariots mentioned in Joshua xvii:18, and in Judges i:19 and iv:3, must have been made of steel. Though uncertain, it is probable that this knowledge of steel came to the Jews from Crete, where wrought iron was probably known at least as early as 2500 B.C.; and steel, by 1800–1600 B.C. This knowledge was brought to Palestine by invasion about 1300 B.C.

Relation of Use of Stone, Bronze, and Iron. Though the Stone Age preceded the Bronze Age, to be in turn succeeded by the Iron Age, these ages do not have definite chronological values, even locally, for there were long periods during which both stone and bronze and, later, bronze

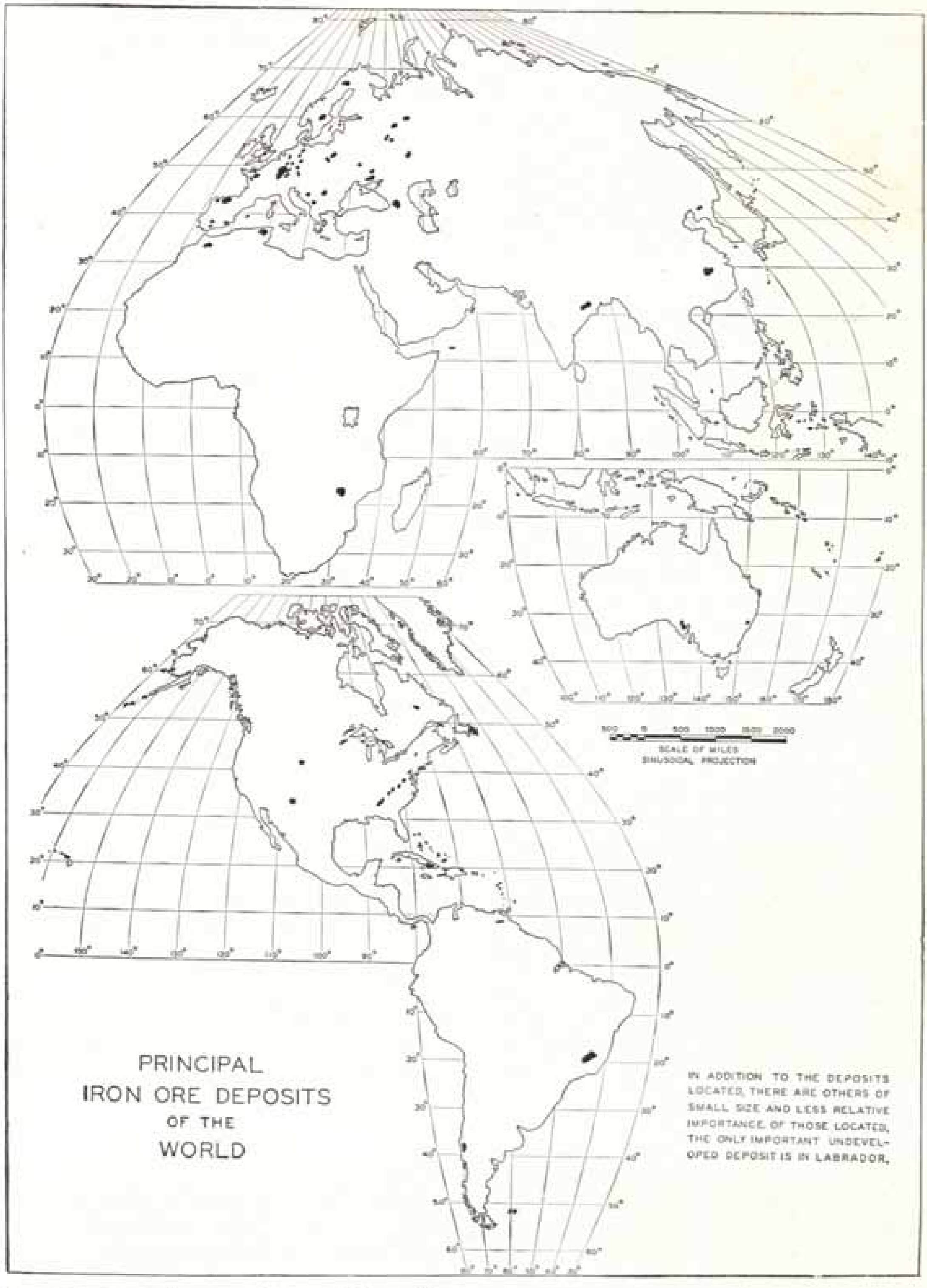


Fig. 212. Principal iron-ore deposits of the world.

and iron were in use in the same area, displacements being gradual everywhere. Further, at all periods, even the present, different stages of development have existed contemporaneously. Again, certain population groups have passed directly from the Stone to the Iron Age, without at any time using bronze implements. Thus the importance, both actual and relative, of certain mineral resources has varied, not only with time, but from population group to population group at a definite time.

Iron and Civilized Man. Our present civilization is based on iron. It is employed in both the machines which manufacture and the products manufactured. Without it, modern systems of transportation would be impossible. It is used in construction; making our clothing; growing, handling, and packaging our food; in supplying our water. Only the air we breathe may be secured without its use, though even this is not always true.

Iron Ores. Metallic or pure iron is seldom found in nature; rather it occurs in combination with oxygen, forming an oxide; or with oxygen and carbon, in the form of a carbonate. In some cases, the oxide is hydrated, or contains chemically combined water. The most important iron ores are the red or gray oxide, hematite; the black oxide, magnetite; the brown hydrous oxide, limonite; and the carbonate, siderite. Even these seldom occur pure and sometimes the impurity, commonly silica or phosphorus, is objectionable. By contrast, if lime, its presence may be advantageous, for lime is used in smelting iron ores.

Though iron ores such as those of the Kiruna district in Sweden, and some in the Adirondacks in New York, were the result of segregation accompanying the cooling of molten rock, many are of sedimentary origin. These latter were formed where weathered iron, carried in solution to the sea, was concentrated in considerable amounts. Similar deposits, known as "bog ores," are formed in fresh-water lakes and swamps. In some cases, the percentage of iron ore in the original deposit was later increased by removal of accompanying soluble material, subsequent to uplift and exposure of the marine sediments. The developed ore bodies of the southern Appalachians have been but slightly altered in this manner. The Lake Superior ores, by contrast, have been greatly enriched, for the area where they occur is a very old land surface, and weathering has been active for a long period of time. Under favorable conditions, weathering of certain types of rock may also produce workable deposits of "lateritic" ores, such as those of eastern Cuba. High-grade iron ores, which can be mined advantageously, contain 50 to 65 per cent metallic iron; if the iron content falls below 30 to 35 per cent, development today under average conditions is uneconomic. In the United States, little is mined with an iron content of less than 50 per cent.

To be of value, a deposit of iron ore must not only be of sufficient size, high grade, and relatively free from objectionable impurities, but it must also lend itself to mining at low cost and be accessible to a market, normally one where coal is available, where demand for iron exists. Few deposits meet all these requirements. Hence, despite the fact that iron is one of the most abundant of metals, many areas lack workable deposits of its ores. In these days of an industrial development based on iron and steel, this lack is a great handicap, particularly in times of national emergencies such as war.

The principal ore bodies which meet the requirements necessary to make them of commercial importance today are found in the southern Appalachians and the Lake Superior region in the United States; in the Lake Superior region of Canada and in Newfoundland; in Cuba; in central Chile in South America; in Great Britain, Sweden, the U.S.S.R., Germany, France, and Spain in Europe. Others of less importance, but of value to Japan, occur in China, particularly in Manchuria, North China, and the Yangtze Valley; and in Malaysia. In addition, there are other deposits, some of large amounts of high-grade ores, of only limited present but great potential importance, especially those of Labrador, eastern Brazil, and northeastern India. All of these are shown in Fig. 212.

Iron Ores of the United States. The iron-ore reserves of the United States are both enormous and well located, and this country leads the world in production. Discontinuous belts of hematite, occurring in the folded beds of the Appalachians from New York to Alabama, have been worked since the Colonial period. These ores are mostly of low grade; on the other hand, their occurrence in association with both coal and limestone has led to their present extensive development in the Birmingham, Alabama, area. Other deposits of

possible future importance are known, both in the interior and the western states, and some of these have been worked recently, but their future in more normal times is uncertain. The most important deposits of all, however, are those of the glaciated highland of the Upper Peninsula of Michigan, northern Wisconsin, and particularly northeastern Minnesota. Unfortunately, these reserves have been depleted seriously during the past few years.

These Lake Superior ores occur in very old crystalline rocks. Of enormous size, many of the occurrences are so near the surface that they can be worked by steam shovel. Even where strip or open-pit mining is impossible, shafts do not have to be sunk to great depths to reach the ore bodies. Not only are the deposits extensive, but the ores are high grade, with an average iron content of about 55 per cent, and impurities are not normally present in objectionable amounts. Enormous reserves of lesser desirability also occur here, in addition to those of high grade, many of these inferior ores being more desirable than some mined and used today in Europe. These are the most valuable iron-ore deposits in the world. Only a short distance from Lake Superior, they move by gravity haul to the ports of the Upper Lakes, particularly Duluth, and from there by cheap water transportation to the ports of the Lower Lakes and to the smelters in and on the margins of the great eastern coal fields. This is a fortunate combination of conditions matched nowhere else in the world.

Coal. Coal is preserved, altered plant material, deposited under swamp conditions which prevented decay, and covered by sediments. The several types of coal result from varying degrees of compression and alteration of the parent material from which they are derived. Originally, the organic material was deposited in horizontal or approximately horizontal beds, and this is still the position of the coal seams in many of the great coal fields of the world. In others, displacement of the strata, in the process of uplift associated with mountain formation, has tilted or sometimes folded the beds and at the same time altered the character of both the rock layers and the coal. Individual seams within coal fields are generally of limited extent, as were the swamps in which the organic material was deposited, but even so the coal field has continuity, for swamp conditions varied in location at different periods of time and vertical levels of the older land surface. For this reason, the shaft of a coal mine may pass through several beds of coal, some thin and some thick, separated by sediments, today solid rock.

Coal formation occurred during various periods of geological time, but not during the earliest, for plant life was not then sufficiently abundant. Apparently conditions were extremely favorable during the so-called "Carboniferous period," the latter part of the Paleozoic era, for it was then that most of the important deposits of coal originated. Coals of the earlier periods, though known, are limited in quantity; those of later origin are generally of lower grade, or less desirable in quality.

In general, the quality of the coal varies with its age and the amount of change the organic material has undergone. If it is relatively young and change has been slight, the coal will be a lignite; by additional alteration, bituminous or soft coals of varying degrees of desirability are formed. Some of these, the so-called "coking coals," are suitable for production of metallurgical coke, used in the smelting of iron ores. Others, with a higher volatile or gaseous content, or with objectionable impurities such as sulphur, are suitable only for domestic and industrial heating and power development. In mountain areas, coal seams have been subjected to both enormous pressure and heat, in connection with tilting and folding of the strata accompanying mountain formation. This metamorphoses or alters the coal, causing loss of volatile constituents and sometimes a change to anthracite or hard coal. It will be noted that the type of coal is related to that of the landform in the area of its occurrence, coals of plains and plateaus ranging from lignites to bituminous; of mountain areas, from bituminous to anthracite.

The ease with which coal can be mined depends upon the location of the seams, the position and character of the rock and coal layers, and the degree of surface dissection. Where near the surface, it may be possible to remove the few feet of overburden and practice "strip-mining," or "open-pit" operations. When the coal seams are deeply buried, however, shafts, sometimes of considerable depth, are necessary. This is often the condition in plain and plateau areas, except as the latter are dissected by stream action, in which case the outcropping coal can be mined by

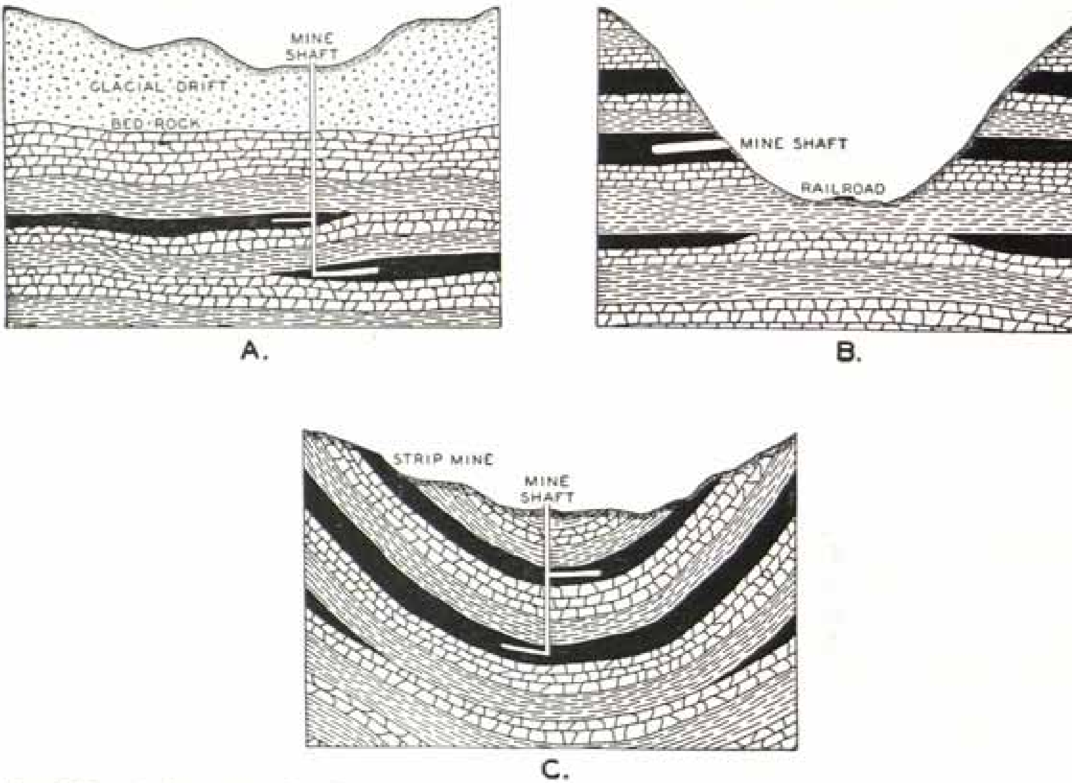


FIG. 213. A. Occurrence of coal and a coal mine in a glacial plain.
B. Occurrence of coal and a coal mine in a dissected plateau.
C. Occurrence of coal and a coal mine in a mountain area.

horizontal shafts into the hillsides. Coal seams in the folded strata of mountains vary greatly in accessibility. Where erosion has locally exposed the coal, it can be mined without difficulty; elsewhere, the steeply dipping beds are difficult to work and, in some instances, they are so badly shattered and interrupted by faulting, or slipping of the strata, that profitable mining operations are impossible.

Coal Resources of the World. Coal is very unevenly distributed, with the bulk of the resource concentrated in central and eastern North America, eastern Asia, northwestern Europe, and Australia. Coal being the principal source of power, and used in the smelting of iron ores, these areas are naturally favored. Our own continent, and particularly our own country, is the most fortunate of all, with North America having reserves of more than 5 trillions of tons, or nearly five-sevenths of the world's total supply. Nearly 80 per cent of this tonnage, and the bulk of the high-grade coals, are in the United States, which not only leads the world in reserves but in production as well. In addition, the fields of the United States are widely distributed, though not all areas are equally well supplied with the better grades of coal. (See Fig. 215.)

Though present production is small, Asia ranks second only to North America in coal reserves, mostly in China, which possibly ranks third among the countries of the world in coal resources. Other Asiatic countries are not so fortunate. Japan, for example, has only small reserves, with most of the coal noncoking and impossible of effective use for smelting iron ores, which forces importation from the Asiatic mainland. Australia's reserves rank next to Europe's, but they are small, though the most important in the Southern Hemisphere, which is poor in coal. Africa is still less fortunate, with most of the small production in the southern part of the continent. South America is the least favored of

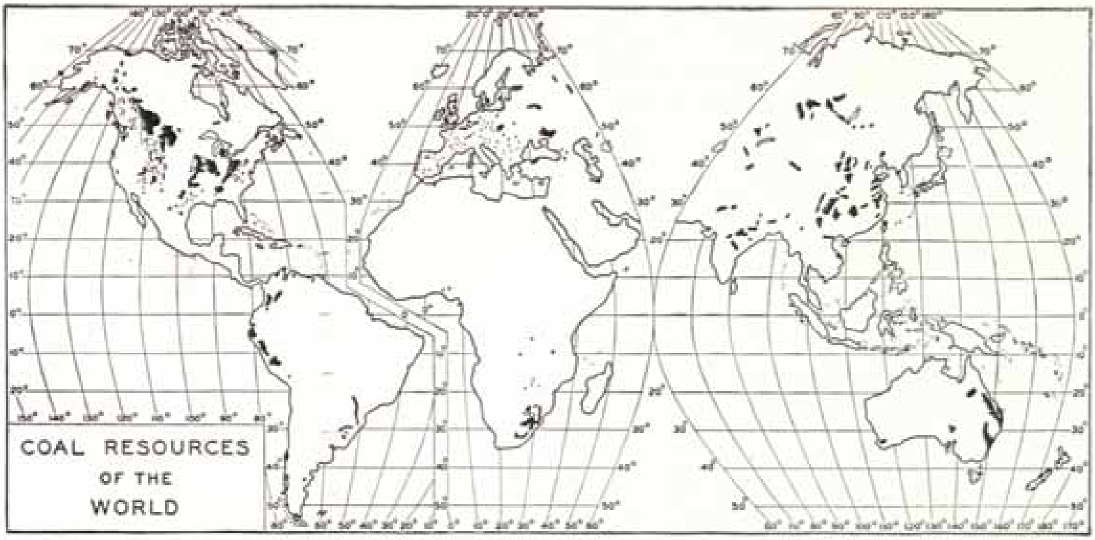


FIG. 214. Coal resources of the world. (After the U. S. Department of Commerce.)

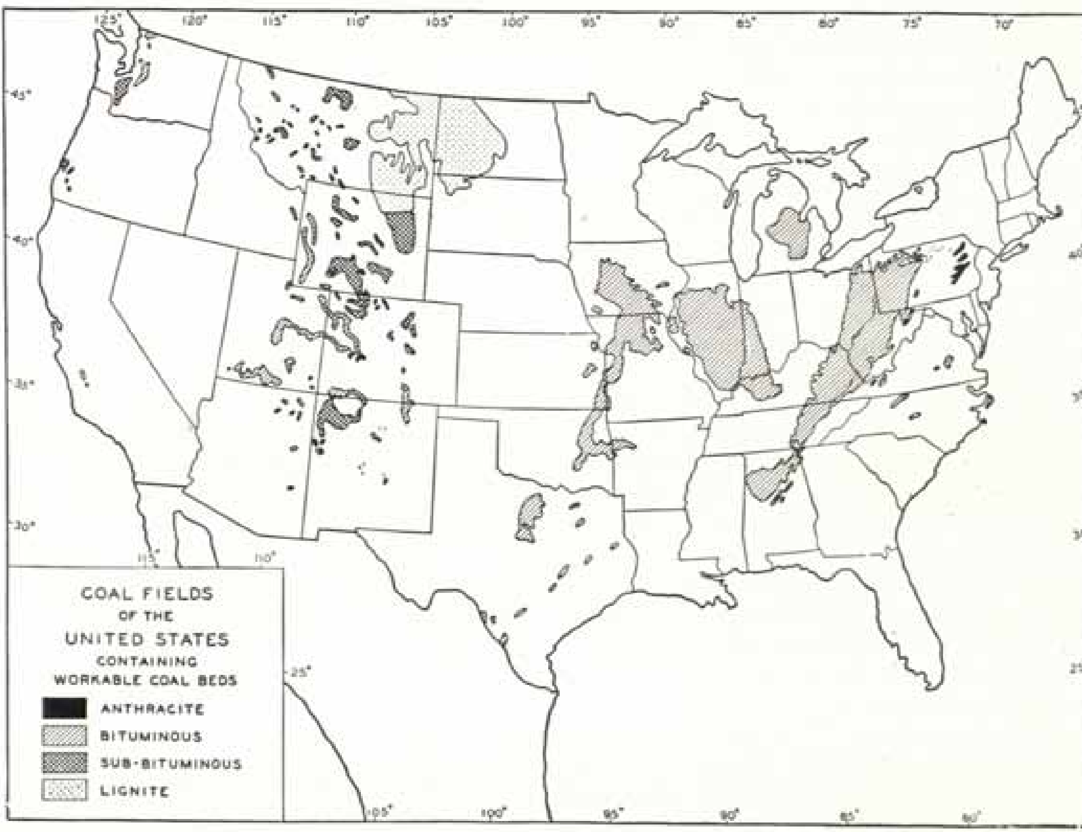


FIG. 215. Coal fields of the United States. (After the U. S. Geological Survey.)

all the continents, with less than 1 per cent of the reserves of North America, and with valuable occurrences confined to southern Brazil, the Peruvian Andes, and central Chile, in all of which areas production is small.

Distribution of Coal and Iron Ores. It should be noted that few areas are fortunate enough to have both coal and iron ores in satisfactory quantity, quality, and location. China has enormous reserves of coal, but little iron ore; India, large iron-ore reserves, but little coal; Japan has adequate reserves of neither. In the Southern Hemisphere, the enormous tonnage of iron ore in eastern Brazil, the only iron-ore occurrence of great importance south of the equator, cannot be smelted to advantage because of lack of coal. The same is true for that of Chile. Only in areas bordering the North Atlantic, and not everywhere there, are both coal of satisfactory quality and high-grade iron ores present and, even there, not often within the same country. Of all the countries of the world, the United States is the most fortunate in this respect. Significantly, the great powers of the present day have developed around the oceanic basin of the North Atlantic. It is fair to assume that the geographic distribution of the two minerals, coal and iron, has been of fundamental importance in producing concentration of industrial development and the importance of these countries in world affairs.

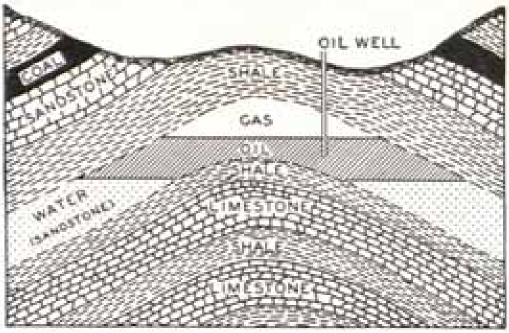
Coal and the Iron Age. It would be almost equally appropriate to call the present Iron Age the "Age of Coal" for, without coal, it would be impossible to smelt iron ores economically and in sufficient quantities to satisfy our needs for iron. Further, we are today at the beginning of a new era in the use of coal. Yet in the not distant past, only 600 years ago, we did not know enough to utilize this valuable resource. In fact, in 1306 King Edward I of England made it a capital offense to burn coal as fuel in London, and one man was executed for the crime. Less than 150 years ago, Col. George Shoemaker was threatened with arrest for attempting to sell a few wagonloads of coal in Philadelphia and, about the same time, the British Admiralty was discouraging its use on vessels. When it was first proposed to make gas from coal, and employ the coke for heating, use of the gas for street lighting was opposed on theological, juridical, medical, moral, police, and economic grounds. The theological objection was that "God divided light from darkness"; the moral, that it would increase crime.

Today, we know enough to burn coal; in the future, we may know enough not to burn it, for coal is a raw material used by synthetic chemists, whose laboratory creations, including explosives, disinfectants, medicines, dyes, and others, appear in ever-increasing numbers to add to our convenience and comfort. Many such products from coal have been known for some time; one which has attracted attention of late is a substitute for silk, but better than the real article for most purposes. What the future holds in store with respect to new uses for coal is unpredictable; the only certainty in many agreeable surprises.

Other Mineral Fuels: Petroleum and Natural Gas. Petroleum, or "rock oil," probably of organic origin, is believed to have been formed by decomposition of marine plant and animal remains. Therefore it occurs in exploitable accumulations only in rocks formed by consolidation of marine sediments. Though occurring in strata of various geological ages, none is found in the most ancient crystalline rocks, and the probability of its presence in areas of considerable igneous or volcanic activity, or where the strata have been badly broken or altered by crustal movement, is very slight.

Petroleum is held in the pore spaces of rocks, much as is water. Sandstones and limestones, which have many such openings, are the oil-bearing layers or "oil sands," so called because sandy strata were the oil-bearers of the first discovered fields. Though such oil-bearing rocks are often apparently solid, fairly productive sands may hold from 3 to 6 quarts of oil per cubic foot of rock. In the old days of unrestricted drilling, about 20 per cent of this was recovered; today, with better practices, this has risen to from 40 to 60 per cent, and possibly somewhat higher occasionally. Sometimes these sands are relatively close to the surface, but often they are at great depths, buried by thousands of feet of younger strata. Inasmuch as petroleum was formed during several periods of past geological time, several oil sands may occur in the same area, but at different levels, so that deep drilling may enable continuance of production after exhaustion of the oil in shallower sands near the surface.

Commercially exploitable occurrences, or



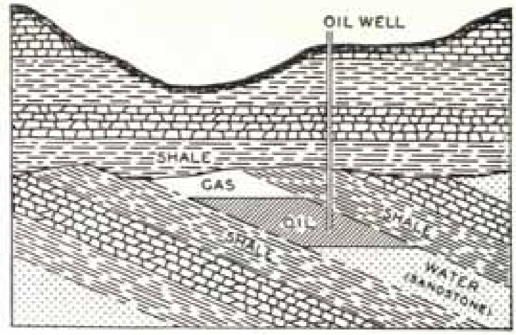


FIG. 216. Diagram to show the structural conditions favorable for the accumulation of petroleum.

"pools," are irregularly distributed, which makes possible the drilling of a dry hole only a short distance from a highly productive well. Large accumulations or pools are found only where the strata contained organic material, the source of oil, or where conditions permitted migration of oil from some source of supply; where porous rock was available to serve as a reservoir; and where rock structure facilitated the separation of oil, gas, and water, which commonly occur together, and prevented escape of the oil from the "sand."

Within oil holding structures, the gas rises to the top; the water sinks to the bottom; the oil accumulates between the two. When such a supply is tapped, gas pressure may cause the well to flow or, if the pressure is very great, the oil may be forced out in great volume. Such a well is known as a "gusher." In many cases, however, pumping is necessary, especially after most of the gas has escaped. Because of the irregularity of occurrence of oil and the fact that the pools are small, below the surface, and often deeply buried, an exact estimate of the world's oil resource is impossible.

Petroleum is likewise obtainable from some compact shales but, though recoverable, except as production is subsidized or under especially favoring conditions, the recovery is uneconomic. It is also possible to manufacture oil by the hydrogenation or chemical addition of hydrogen to coal, which converts the carbon of the coal into hydrocarbons or petroleum. In the future, when other sources of supply have been seriously depleted, we may be forced to turn to our enormous deposits of oil shales in the western mountain states or resort to treatment of our abundant coal in the east to supply the oil which is today obtained by tapping natural reservoirs. When that time arrives, petroleum and its derivatives, including gasoline, will be much higher in price than at present.

Petroleum in the Americas. Long known from seepages, petroleum or rock oil was first obtained by drilling in 1859. Its industrial use, dating from that time, rapidly assumed importance with invention of the internal combustion engine and its use in automobiles. Nature's endowment of this country has been generous indeed, including among other assets an oil reserve unequaled elsewhere in the world, distributed among the fields shown in Fig. 217. From them have been produced more than 20,000,000,000 barrels of petroleum, yet they still continue to yield at the rate of nearly 1,500,000,000 barrels of oil each year. Production started in the Appalachian Field, which has been a consistent producer; the other fields were developed later. Of them, the Mid-continent Field is today the most important oil producing area in the world. Of the other fields of the United States, those of California are second in rank.

Latin America contains several important fields in the region bordering the Caribbean Sea. The most important Mexican fields are on the east coast, in the vicinity of Tampico and to its south; in northern South America, they occur from Colombia east through Venezuela to the island of Trinidad, with production most important in Venezuela. Less is known concerning the extent of the petroleum reserve of the remainder of the continent, though both Peru and the Argentine have producing fields and there is much relatively unexplored territory.

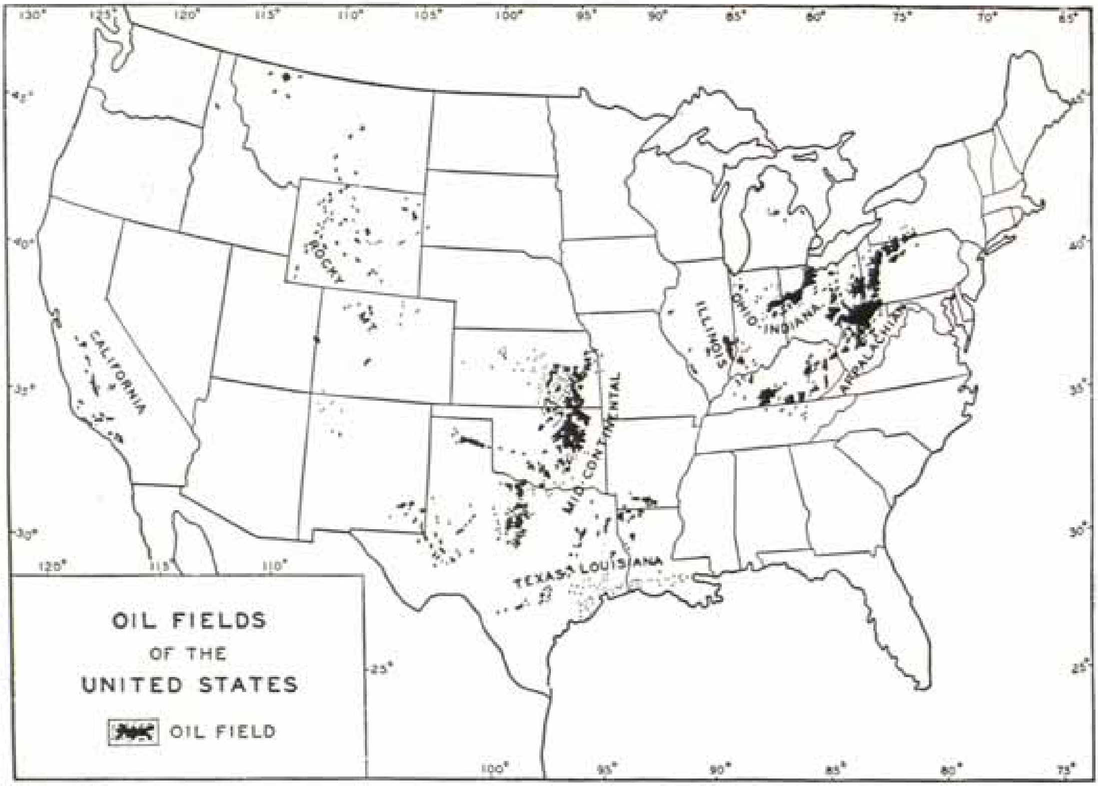


FIG. 217. Oil fields of the United States. (After the National Resources Committee and others.)

Petroleum in the Eastern Hemisphere. The most important of the known oil fields of the Eastern Hemisphere are also north of the equator, mainly in Eurasia. Unfortunately, the Southern Hemisphere is almost everywhere lacking in known, large reserves of the valuable resource, petroleum, the only important occurrences discovered to date being those of the East Indies. Further, when the distribution of petroleum for the world as a whole is considered, it is rather significant that none of the great powers of western Europe has a sufficient local supply, but must depend on ownership or financial control of outside sources for this necessary mineral fuel.

The oldest and most productive fields of Europe are those in the area bordering the Caucasus Mountains and to the west of the Caspian Sea. Of these, the best known and most important is near Baku. It is this field which makes the Soviet Union the most important Old World producer and, considering the vast extent of promising unexplored territory, the probable leader for many years to come.

There are two important producing areas in Asia: one in the southwest, the other in the southeast. In the southwest, the most important fields are those near the Persian Gulf, in Iran, or Persia, in Saudi Arabia, and in Iraq. These have been developed under concessions granted to Western powers, the securing and retention of these rights to exploit the resource being a constant source of contention between the interested nations, often leading to the exertion of considerable outside pressure on the underdeveloped countries possessing the resource. In southeastern Asia, there are relatively small fields in Burma, but the bulk of the reserve, largely unexploited, is in Sumatra and Borneo. Elsewhere in Asia, including Japan, known reserves are small and important discoveries of petroleum are improbable.

Our Supply of Petroleum. Our supply of petroleum in the pools, even in the United States, is

exhaustible, and when it has been dissipated, though other sources of supply are known, they will be much less satisfactory. It is not known exactly how long our present annual output of more than 1,250,000,000 barrels can continue undiminished for, though some of the older fields are either partly or completely exhausted, both new fields and new sands of some of the older fields come into production almost yearly. If the reports of the National Resources Board and of the United States Bureau of Mines are accepted as authoritative, however, production will decline materially by 1950 and, irrespective of whether this is correct, it is certain that the life of the resource is limited, and certainly not long. Further, its life has been decreased materially by the war. Production will not, of course, disappear completely for many years, but the decrease which must occur in the not distant future will make for scarcity and accompanying high prices, as larger and larger dependence on other sources for petroleum is enforced by increasing depletion of the supply stored in liquid form in the rocks. In view of this fact, there is urgent need for conservative practices in drilling, which enable more complete recovery of the oil and effective use of petroleum in order to secure maximum benefits from its consumption.

Natural Gas. Natural gas occurs in association with oil, but occasionally is found alone. It generally accumulates under sufficiently great pressure so that it can be transported by pipe lines for considerable distances without the necessity for using artificial means to induce flow. Used as an illuminant, for domestic heating, for generating power, and for the manufacture of carbon black, which is necessary in rubber manufacture, natural gas is a resource of great value. Practically all oil fields yield such gas, much of which, unfortunately, is used wastefully. This is another place where conservation should be practiced.

Other Metallic Minerals. The scope of this elementary consideration will not permit more than a brief statement of the general areas of occurrence of the metallic minerals other than iron. Important deposits of such minerals, with a few exceptions, are found only where crustal deformation is active at present, or where its past activity is evidenced by the presence of hard, crystalline rocks. An exception to this rule is the occurrence of lead and zinc ores in horizontal, unaltered rocks in Missouri and Illinois in the United States; and, under corresponding conditions in Europe, in Poland. Again, aluminum, one of the major metallic components of the earth's crust, is widely distributed in common clays, though the commercial source of the metal, bauxite, is not so common. In considering the extent of reserves of the metallic minerals, it should be borne in mind that present known distribution of commercial deposits is not only incomplete, but that technological advances will probably alter our present evaluation of many of the known ore bodies.

Highlands and Mineralization. Though occurrences of metallic minerals are largely confined to highlands, not all highlands, nor even all mountain areas, contain economically important deposits of those minerals. Some, in which no such deposits are known today, may later, after more complete exploration, become important producers, but in many highland regions which have been thoroughly prospected there are no such deposits. For example, the Alps, the geological structure of which has been studied in great detail, have been subjected to intensive exploration without discovery of important, commercially workable deposits of metallic minerals. In our own country, the same is true to a lesser degree of the Appalachians, except for the iron ore, and it is equally true for many mountain areas elsewhere.

Commercial Deposits of Metallic Minerals. To be commercially exploitable, ores of the metallic minerals must contain enough of the metals in either a pure or combined state so that their extraction is economically justified. When the metal occurs pure or "native," as gold and copper sometimes do, crushing and washing of the ore, or concentration carried out in some other manner, may be sufficient; when the metal is combined with other elements, as is more commonly the case, additional chemical treatment is necessary.

Commercial deposits of metallic ores are the result of natural concentrations occurring during the cooling of masses of melted rock intruded into the strata, or of deposit from solution, as veins in the solid rock. These processes are most active in areas where crustal movement and volcanic activity are pronounced, for there waters are heated and contain chemically active materials in solution, and intrusions of melted rock are common. Because of these facts, deposits

of the metallic minerals are more numerous in mountains and other highlands than in plains, and most of the metallic mineral wealth of the world is concentrated in such areas. Further, erosion is active in regions of considerable elevation, so that the deposits are more easily located. For these reasons, mining of metallic minerals is largely confined to highlands, though not all of these are necessarily of great elevation, for favorable conditions occur in the "roots" or worn-down remnants of formerly lofty mountains, as well as in younger highlands of greater present elevation.

Productive Mineralized Regions of the Americas. These include the Laurentian Highland, which stretches westward from Labrador, largely north of the St. Lawrence River, from which it derives its name. This is a very old, heavily glaciated area, with hard, crystalline rocks. This highland not only possesses valuable iron ores, but it is also the world's most important source of nickel, normally furnishing 99 per cent of our supply. It also has copper, gold, silver, platinum, and cobalt ores, in addition to pitchblends, from which radium and uranium may be obtained. In fact, this area today affords the most important known supply of uranium in the world. Only partly prospected, this region holds forth much promise as a future source of supply for many metallic minerals. A second important mineralized highland of the Americas is the great cordillera or mountain axis which extends from Alaska to Cape Horn. In this area, copper is secured from several large, widely scattered occurrences in both the Americas. It also supplies gold, silver, platinum, lead, zinc, mercury, antimony, tungsten, and other metals, including iron. A third productive area, made up of a number of plateaus and mountains, though probably of less importance than the other two, is that of the highlands of Cuba, the Guianas, and eastern Brazil, which in addition to iron ores have gold, silver, chromium, manganese, bauxite, and other metallic mineral resources of importance, 93 per cent of our bauxite, from which aluminum is obtained, being supplied by the Guianas. During the war, nickel has been produced in Cuba, but whether this will continue in normal times is rather uncertain.

Productive Mineralized Regions of the Eastern Hemisphere. In Europe, valuable deposits of metallic minerals are known in the Ural Mountains, an important source of platinum; and commercially exploitable deposits of iron, chromium, and mercury occur around the borders of the Mediterranean in Spain, Italy, Greece, and Turkey. Central and southern Africa contain several important producing areas which furnish copper, gold, and chromium. In southern and western Australia, the presence of gold, silver, lead, zinc, and other valuable minerals of lesser importance serves as the basis for an important mining industry. In Asia, there are several mineralized areas in addition to India, mentioned in connection with iron ores. Southeastern Asia is an important producer of tin; the mountainous area of China, south of the Yangtze, is the world's most important source of antimony and tungsten, in addition to supplying lead, zinc, tin, and other metallic minerals. A third important mineralized area extends westerly from the Okhotsk Sea through southern Siberia. Largely unproved as to its mineral resources, which are probably extensive, it is today one of the world's most important gold-producing regions.

Desirability of a Local Supply of Metallic Minerals. Today the list of important metallic ores is long and, with development of new uses for metals, it lengthens and the quantities required increase yearly. For these reasons, possession of commercially exploitable deposits becomes a factor of increasing importance in determining the potentialities of an area. This is particularly true for a fundamental and bulky mineral like iron ore, which cannot be used to advantage except where it is easily accessible from the consuming area and, with maximum effectiveness, only if it occurs in conjunction with coal, used in its smelting. Some of the metallic minerals, however, are neither bulky nor used in great quantities. These can be marketed to advantage farther from the producing region. For example, one partly loaded ship would afford a year's supply of mercury for the United States; by contrast, the ore of aluminum, bauxite, both bulky and used in greater quantity, requires much cargo space.

Despite the small volume of many of these metallic minerals required, they are all vital to modern industry. For example, without chromium, manganese, nickel, and tungsten, all used in relatively small amounts, many of our modern steels could not be made. Unfortunately, adequate local supplies of many minerals may be

lacking, even in a country as nearly self-contained as the United States. Therefore dependence must be on import. Thus, in the most recent list of "strategic materials" compiled by the United States Army and Navy Munitions Board, materials secured either largely or entirely by import but essential to our economic welfare in times of peace and for defense in time of war, are included: antimony, chromium, manganese, mercury, nickel, tin, and tungsten. Of the complete list of 14, 7, or 50 per cent of all, are metals; 2 more, mica and quartz crystal, are nonmetals.

Other Nonmetallic Minerals. Other than the mineral fuels which have been considered earlier in this chapter, the most important of the nonmetallic minerals are building stone, gravel, sand, and lime, used in construction; clays, used for making brick, tile, and utensils; abrasives, necessary for certain industrial processes; salt, other saline substances, lime, and sulphur, which serve as the raw materials for chemical industries; the fertilizers; and gems, some used in industry. The number of these minerals is too great to permit consideration of more than a few of the most important and, of these, only limited discussion. Therefore attention will be confined to some of those used in construction and utensils, the chemical industries, and fertilizers.

Nonmetallic Minerals Used in Construction and Utensils. Stone has been a favored building material almost from time immemorial, and it still ranks high in both desirability and the extent of its use. Because of its bulk, it does not normally travel far to market except when it is of unusual beauty or desirability, for example, some marbles and limestones: the first used for statuary, the latter in lithography. Under such conditions, markets are world wide. To a lesser extent, and within a smaller area, this is also true for the even-textured limestones of Indiana, the well-known granites of New England, the "Rock of Ages"; and for certain slates, the cleavage of which permits use for roofing. All of these are likewise pushed by effective sales organizations, which foster widespread demand. Broken or crushed, and in the form of gravel, rock is used in great quantity, not only for building, but for road construction. These needs are commonly satisfied from near-by sources of supply, for few areas, except those buried deeply by alluvial or loessal deposits, lack rock of some type, suitable for such uses.

Sand, lime, and clay are used either directly or indirectly in construction and likewise are industrial raw materials. Not all types of these substances are equally desirable for these different uses nor is any one type suitable for all. Sand for building construction, for example, is very different from that suitable for abrasive use or for the manufacture of glass. Similarly, clays perfectly satisfactory for making brick and sewer tile are of no value for the manufacture of fine pottery and porcelain. Hence areas having deposits of these nonmetallic minerals suitable for special uses have assets, often of considerable value, which may, and frequently do, serve as the basis for development of specialized industries.

Nonmetallic Minerals Used in the Chemical Industries. Salt and other saline substances, both used in the chemical industries, are obtained by evaporation of sea water, from wells which yield natural brines, deposits of rock salt, and the waters and beds of desert lakes, either partly or completely dry. Not only do some of these substances play an important part directly in our everyday life, salt being a necessity for both man and the animals, but all are used extensively in many chemical industries, as in southern Michigan and western New York. Fortunately, most of the important industrial areas, and those with dense populations, have adequate supplies of salt and other essential saline substances.

Sulphur is used in many industrial processes, being employed in the production of sulphuric acid, which is used in the manufacture of oil, rubber, explosives, and many other products. Formerly obtained from areas of volcanic activity such as Italy and Japan, approximately 80 per cent of the present world supply comes from the Gulf Coast region of Louisiana and Texas, where it occurs in association with petroleum and rock salt, and is obtained by pumping from deep wells, the sulphur first being liquefied by forcing highly heated steam through the beds where it occurs.

Nonmetallic Minerals Used for Fertilizers. These include lime, nitrates, potash, phosphates, and others of less importance. Addition of these substances to soils is often necessary to secure satisfactory production. Of lime, also used as a flux in the smelting of iron ores, there is often an adequate local supply. Important deposits of nitrates, potash, and phosphates are, however, more uncommon and therefore often of great value to the areas which possess them.

The most important of the natural deposits of nitrates are those of the Atacama Desert, in northern Chile, where the practically rainless conditions have favored the accumulation and preservation of beds of sodium nitrate. For many years, an export tax on this mineral was the principal support of the Chilean government. Of late years, synthetic nitrates, or those made artificially, have destroyed this natural monopoly so long enjoyed by Chile.

Potash is found in beds, like rock salt, with which its occurrence is frequently associated. The largest and most important deposits are those of western Europe, principally in Germany and Alsace, where it is mined at depths of 1000 feet or more. It is also secured from New Mexico in this country, this source supplying 50 per cent of our needs in normal times, and all of them during the war.

The essential element in phosphates is phosphorus, present in considerable quantities in bones and animal wastes, frequently used as fertilizer. It is likewise a component of the nonmetallic minerals known as "phosphates," which are found in various types of occurrences, including lenses in limestones, residual deposits, placers, and others. The United States has the most important of the world's reserves: some in the southeastern states, particularly in Florida, and even larger deposits in the western states. In all, these reserves are estimated to contain 13,500,000,000 tons, or 55 per cent of the world's known supply. Much of the production of the southeastern states is for export to the Old World, for the soils of many agricultural areas of western Europe are deficient in this important mineral. Other important deposits are known for northern Africa, Siberia, and some of the islands of the Pacific. It will be noted that these three important fertilizers, nitrates, potash, and phosphates, are very unevenly distributed, and that no single country has an adequate supply of each.

Local Supplies of the Nonmetallic Minerals. Fortunately, distribution of most of the nonmetallic minerals permits essential national self-sufficiency in countries of moderate to large size, except occasionally in the mineral fertilizers and a few other nonmetallic minerals with special, though often essential uses. For example, in the list of "strategic materials" compiled by the United States Army and Navy Munitions Board, only two nonmetals, mica and quartz crystal, are listed. For these, we depend on Brazil, which supplies all the quartz crystal and somewhat less than one-third of the mica; on India for more than half of the mica; and on Canada for the remainder of that mineral in normal times. Considering our national deficiencies in both the metallic and nonmetallic minerals, southeastern Asia, which does supply most and could supply all our needs, except for quartz crystal and mercury, is a highly important area from a national economic point of view, which explains in part our great and proper interest in the affairs of that part of the world.

The Function of Mineral Wealth. Mineral wealth generally plays but a small part in the economic life of an area until relatively late in its history, partly because its existence or value may be unknown, and partly because its exploitation may be impracticable, or even impossible, before a certain degree of development has occurred. It is only under exceptional conditions such as "gold rushes," therefore, that mineral wealth has been either the sole or the original incentive for human occupation of an area.

During the earlier periods of history and stages of human development, the presence of mineral wealth in an area was relatively less important than today. This resulted in part from earlier lack of knowledge of the value and use of many such deposits. Again, it was due to man's inability to use them effectively, even when their occurrence and value were known. It was also in part because a local source of food supply, water, and material for shelters, clothing, and other uses was of so much more fundamental importance in determining relative areal desirability. From the standpoint of less advanced populations, and at the time of initial occupations of earlier periods, the presence of mineral wealth was, therefore, at best of only secondary importance. For many years, for example, though coal seams, outcropping on the hillsides and today mined extensively, were quite generally known to occur in the dissected Cumberland Plateau, wood was the usual fuel. Similarly, the enormous iron-ore resources of northeastern Minnesota were unexploited until long after the date of first white settlement in the state.

Mineral resources at present, however, have assumed great significance in many areas, formerly considered of little if any value, and have acquired great importance in their effect on the

character of the economic development of the country in which they occur. In fact, so much importance attaches to possession of adequate supplies of coal, iron, and petroleum in these days of complex industrial development that no great nation feels secure without control of sources of these necessary raw materials. Without recognition of this fact, it is impossible to evaluate many national policies intelligently. In addition to the mineral resources mentioned, without which important industrialization as we know it today would be impossible, a long and continually lengthening list of others plays a part in many of our industrial processes. Thus, as time has passed, mineral wealth has come to assume an ever-increasingly important function in our life.

Though necessary for the economic welfare of all populations, mineral wealth is very unevenly distributed. No nation, in fact, has enough of all commercial minerals; even the United States, the most nearly self-sufficient of all, imported about 70 varieties during the war. Since in minerals, as in all other aspects, international interdependence is a fact, necessary supplies must be available to all to ensure a peaceable world. The existing struggle for such supplies, made doubly intense by their alarming depletion during the past years of war, must result in continuing friction, which can be prevented only by international control and allocation of unexploited resources in areas with a low present stage of development. Not only would this tend to ensure an equitable division of available raw materials, but it would likewise present an opportunity to check would-be war-making nations.

Whether the presence of any particular mineral resource will affect the desirability of an area varies, not only with its stage of development, but with the following factors as well: (1) the size of the deposit, (2) its quality, (3) its location, (4) the cost of working the deposit, and (5) market conditions.

The first of these, the size of the deposit, varies with the mineral. Occurrences of coal or iron ores, of low value per unit of weight, must be large to be of economic importance. By contrast, a smaller occurrence of gold, silver, or some other precious metal, can often be developed to advantage. Even though the source of supply is large, its exploitation may be uneconomic if the production must meet the competition of higher grade deposits. In the United States, for example, there are enormous reserves of low-grade iron ores and huge tonnages of inferior coals which cannot be developed profitably so long as more valuable sources of supply are available. Location is important in all cases, but particularly so for the bulky minerals and deposits of low grade. Gold, for example, may be mined to advantage wherever its existence in paying quantities is known; coal, only where good transportation facilities exist. Many mineral deposits, though large and high grade, are impossible of profitable development because costs of working are prohibitively high. This may result either from the great depths of the deposits or unfavorable conditions of the strata in which they occur. Again, market conditions may be the critical factor in determining the economic importance of an occurrence. At the present time, for example, many submarginal gold and silver mines are operated only because of governmental purchases of gold and silver which make operations profitable.

Where mineral wealth is abundant, varied in kind, and economically exploitable, it affords a basis for important industrial development. Without the mineral fuels, coal and petroleum, for example, the world's existing industrialization would be impossible. Therefore their presence or absence, and their availability, affect regional potentialities fundamentally. For example, it is the enormous, easily accessible reserves of these two important minerals which makes possible the important manufacturing industries of certain sections of this country where such sources of power are available. It should be realized, of course, that mineral fuels alone, even in combination with other mineral resources, will not ensure industrial development, but only permit it if other conditions are favorable.

This is because the particular economic activities which serve as the basis for man's support in any given area result from various causes which make their development a possibility. These include, not only favorable natural conditions, but stage of development and governmental stability and attitudes as well. Therefore, unless a certain stage of development has been attained, and both governmental stability and attitudes are satisfactory, even favoring natural conditions such as valuable mineral resources will not insure their development and use as a basis for important industrialization such as we have among advanced populations today.

QUESTIONS AND EXERCISES

1. What mineral was commonly used by Paleolithic and Neolithic man for making implements? What others were used occasionally? Why are these adapted to such use? What are their limitations?
2. Why is copper poorly adapted to making cutting tools? How is it improved for such use by the addition of tin? Why was general use of bronze delayed until trade began?
3. Why is it appropriate to refer to iron as the "Proteus of metals"?
4. Where are the first definite references to steel found? Where did manufacture of steel probably originate? Why is the history of steel so obscure?
5. Why do the Stone, Bronze, and Iron ages lack definite chronological values? Give an example of a population group which has passed directly from the use of stone to that of iron.
6. What are the principal forms of occurrence of iron ores? How were such ores formed? Under what conditions is a deposit of iron ore of commercial value? How does proximity of a deposit of iron ore to one of high-grade coal affect its value? Why?
7. Where are the important iron-ore reserves of the world located? Contrast the iron-ore reserves of the Northern and Southern hemispheres. Discuss the iron-ore resources of the United States. Why are the ores of the Lake Superior region particularly valuable?
8. Name the mineral fuels. How is coal formed? Name the different types of coal and state the values of each. What causes the difference in these types of coal? What is a "coking coal"? For what is it used?
9. How and why do coal seams differ in the ease with which they can be mined? What is the extent of our coal resource? Where is it located? Of what types are the coals?
10. Where is the bulk of the world's coal concentrated? What are the different types of coal mining? Contrast the coal resources of the Northern and Southern hemispheres.
11. Why might it be appropriate to call the present the "Age of Coal"? State briefly the changes which have occurred in the use of coal during the past 600 years.
12. How was petroleum formed? How and under what conditions is it stored in the rocks? Discuss the location of the world's oil reserves.
13. Under what conditions does natural gas occur? What is its value and for what is it used?
14. Why are occurrences of metallic minerals more common in highlands than in plains? Why are both discovery and working of such deposits in highlands easier than in lowlands?
15. Where are the principal mineralized highlands of the world located? Are all highlands mineralized? If not, name one that is not mineralized.
16. Why is a local supply of many metallic minerals desirable, even though they can be transported economically? What "strategic" metallic minerals do we lack? What are our present sources of supply? Why does this make southeastern Asia important to us?
17. Name some of the more important nonmetallic minerals, in addition to the mineral fuels, and state the principal uses of each. Why are most nonmetallic minerals used near the areas of production? State some exceptions to this general rule.
18. Why is sulphur of great importance to man? From where is most of the world's supply obtained today?
19. Name the important mineral fertilizers and state the most important source of each. Why are the mineral fertilizers of such great importance to man?
20. What important nonmetallic minerals of strategic significance are lacking in the United States? What are our sources of supply for these minerals?
21. Why does mineral wealth generally play only a minor part in the economic life of an area until relatively late in its history? Illustrate this fact by an example.
22. Why is mineral wealth of only secondary importance to less advanced populations? What place does mineral wealth occupy in our present civilization? In influencing international relations?
23. Is the list of important minerals increasing or decreasing? Why? What factors determine the desirability and value of an occurrence of any given mineral? Do the size and location of a deposit affect the commercial value of occurrences of all minerals in equal degree? Why? How do the grade of a deposit and market conditions affect the possibility of economic production? Illustrate by examples.
24. To what extent does mineral wealth influence the amount and type of industrialization of a region? Does mineral wealth ensure industrial development? Why? Illustrate by example.

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This atlas consists of maps showing the distribution of mineral production, accompanied by some explanatory text.

Chapter Twenty-Five

THE OCEANS AND THEIR COASTS

Extent of the Oceans. The oceans, not the land masses, are the areally dominant surface features of the earth, covering nearly 72 per cent of its exterior to an average depth in excess of 2 miles. Even the least extensive of them all, the Arctic Ocean, is more than one and one-quarter times the size of Australia, the smallest of the continents; the largest, the Pacific, exceeds the combined area of all the land masses by 25 per cent. There is so much water, indeed, that were the surface irregularities of the earth's solid crust smoothed out, the ocean would everywhere be nearly 2 miles in depth. Further, and of great importance to man, the oceans are continuous, whereas the land masses are interrupted.

The Depth of the Ocean and the Character and Topography of Its Bottom. Our knowledge of the depth of the ocean, and of the character and topography of its bottom, is most complete along the shore lines of the great nations, where detailed mapping of the coasts has been carried out and extensive, accurate soundings have disclosed the nature of the bottom and the depth of the overlying water immediately offshore. For more remote coasts and the open ocean, information is less complete. In general, however, the ocean bottom consists of: (1) a continental shelf, bordering the great land masses; (2) a continental slope to the ocean basins proper; and (3) the ocean basins, rimmed by the continental slope.

The continental shelf, representing the submerged, marginal portion of the great land masses, which it borders with variable width, slopes gently seaward as a fairly level, submerged plain, at an average rate of 1 or 2 feet to the mile. This is a very slight slope. In places, irregularities of its generally smooth expanse rise almost to the surface of the ocean as banks or shoals, or even above the water to form islands such as Long Island. Elsewhere, it is crossed by linear valleys. Some of these are canyonlike, with depths of 2000 feet or more; others are shallower, with more gently sloping sides. In most cases, these departures from the general level appear to be related to topographic features of the near-by land, valleys under water, for example, being continuations of those on the adjoining land. Everywhere over the continental shelf the water is shallow by comparison with most ocean depths, ranging from a few feet near the shore to 600 feet at its outer edge. Over its submerged surface are spread gravel, sand, and clay, the type of deposit varying with: (1) material afforded by the adjacent land, the source of supply; (2) distance from shore; and (3) degree of disturbance of the water in which deposition occurs. In places, where conditions are favorable for organic life, deposits of calcareous or limey material, secreted by marine organisms, may occur. All these deposits tend to obliterate minor surface irregularities and their quantity may even be sufficient to cause slow seaward extension of the continental shelf. This generally flat plain which borders the continents is estimated to have a total area of approximately 10,000,000 square miles, almost equal to that of Africa, the second largest of the continents, and to occupy about 5 per cent of the ocean bottom.

Beyond the outer margin of the continental shelf the slope of the ocean floor increases to an average of 100 to 200 feet to the mile, with occasional more abrupt descents to the abyssal depths of the great ocean basins. Though not precipitous, except locally, these slopes are far above the average in steepness for most of the ocean bottom, and they are of further significance in that they completely encircle the ocean basins. Over them are spread the finer sediments which,

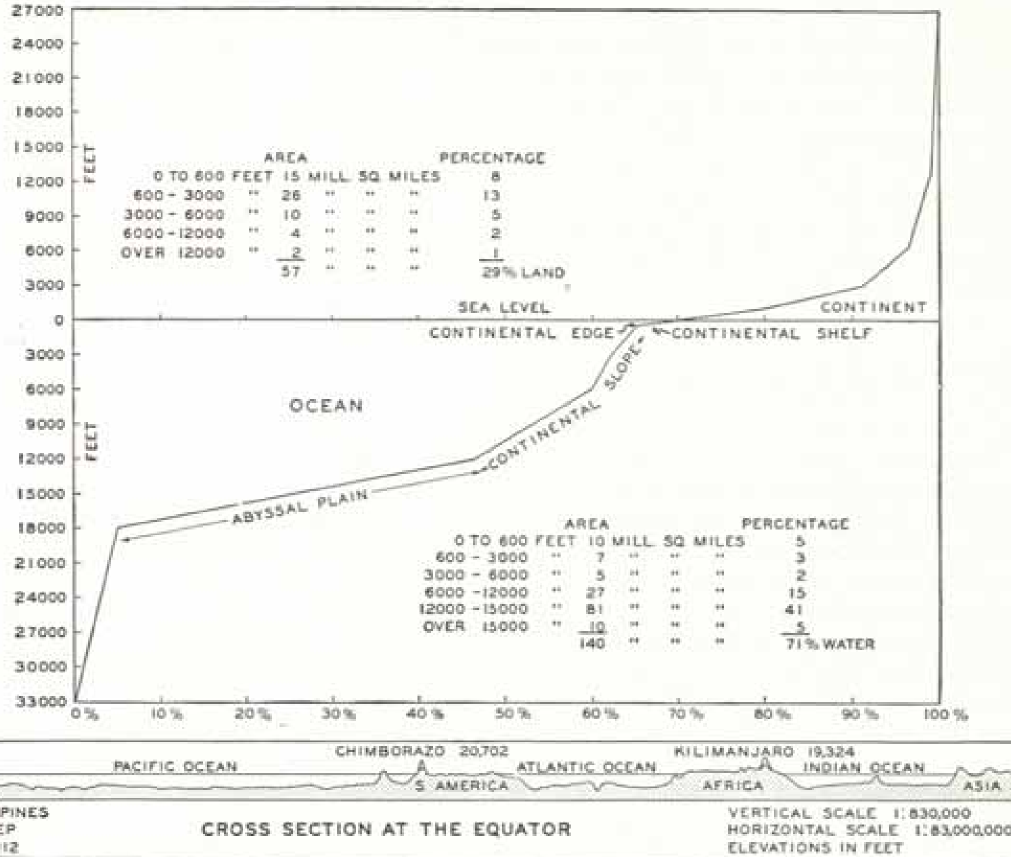

FIG. 218. *Top:* The proportion of the ocean at various depths. (After Murray.)
Bottom: A cross section of the land masses and the oceans along the equator. It will be noted that the ocean depths exceed the elevations of the land.

remaining in suspension for considerable periods of time, are carried farther out to sea before deposition occurs.

On the seaward side of the continental slope are the great ocean basins, believed to have been formed by crustal movement, in which the average depth of the water exceeds 2 miles. Of the five great ocean basins, that of the Pacific is deepest, averaging 2¾ miles. The general monotony of the floors of these great basins, which cover 75 per cent of the ocean bottom, is interrupted by occasional irregularities: some, uplifts like the Hawaiian Islands, volcanic in character; others, linear depressions known as "deeps." In all, there are 72 of these, with at least 6 in which the water is more than 5 miles deep, and one, the Swire Deep, east of the Philippines, with a depth of 34,218 feet, or nearly 6½ miles. Such a depression is a greater departure from sea level than the loftiest of mountains. Nearly thirty-four times the maximum depth of Lake Superior, the deepest of the Great Lakes, it makes all bodies of fresh water seem shallow by comparison. At depths of less than 2½ to 3 miles, oozes, composed of the remains of surface organisms, volcanic ash or finely fragmented volcanic material, very fine sediment from the land, and other fine material, cover the bottom; at greater depths, a red clay, the color of which results from oxidation of iron in the minute particles of which the clay is composed.

The Water of the Ocean. The water of the ocean is saline. Not only does it contain common salt in solution but other mineral matter as well, largely supplied by rivers and concentrated by evaporation to an extent that average sea

water contains 3½ pounds of dissolved solid material in each 100 pounds of water. In one respect, this salinity is an advantage to man in that it decreases the draft of vessels, thus increasing the utility of many harbors. In all, it is estimated that there is at least 20 per cent as much mineral matter in the sea as in the land above sea level. Of this mineral matter in sea water, nearly 78 per cent is common salt. This may appear peculiar, since calcium carbonate is more abundant than salt in the fresh water of rivers which supply the mineral matter, unless it is realized, that, not only do animals withdraw calcium carbonate or "lime" to form shells and similar structures, but that it is likewise removed by precipitation, whereas salt commonly remains in solution. Though movements of ocean water tend to cause uniformity in the amount of dissolved mineral matter everywhere, certain enclosed seas like the Red Sea, in which the rate of evaporation is high and the inflow of fresh water from the land is small, are more saline than the Arctic Ocean, where evaporation is slight and melting ice contributes much soft water.

Light in the Ocean and Ocean Temperatures. Light penetrates only a short distance below the surface of the ocean. Even at depths of only 2000 feet, there is too little to enable normal vision; at those of a mile or more, there is none except that emitted by phosphorescent animals. Temperatures vary with latitude, and between the surface and the ocean bottom. Surface temperatures, even in the tropics, seldom rise materially above 75° F., decreasing poleward to 28° F., the freezing point of the saline waters in Arctic seas. Seasonal changes of temperature are slight, for water both warms and cools slowly. Therefore oceans are great equalizers of temperature over bordering lands, if air movement is from the water toward the land. At depths, the temperature differences noted for surface waters are even less marked. There is no change from day to night, nor from summer to winter, and temperatures at great depths are uniformly low, ranging from slightly less than 32° F. to not more than 40° F. It should be realized that conditions in enclosed seas may depart materially from those which exist in the open ocean.

Conditions at the Bottom of the Ocean Basins. No portion of the earth's land surface equals the great depths of the ocean in monotony. Miles in extent stretch great plains covered by oozes or red clay. Temperatures are low, seldom more than a few degrees above freezing and often below the freezing point of fresh water; daily and seasonal changes of temperature are lacking; perpetual darkness prevails. Pressures rise to 6 tons to the square inch and the water is highly charged with carbon dioxide, since the drift of water which supplies the small amount of oxygen present is not great enough to carry the carbon dioxide away completely. This increases the solvent action of the water, but decreases opportunity for organic life. The limited life of this deep-sea area is made possible only by a rain of organic remains, the food supply, from the surface waters above, and oxygen dissolved in the slow drift of cold water which penetrates to these great depths.

The Surface of the Ocean. The surface of the ocean, which appears to be flat over limited areas, actually conforms to the curvature of the spheroidal earth. Important departures from this form, resulting from the pull of gravity, are sometimes caused by lateral attraction of the land masses which border the oceans. This attraction varies with the mass of the land, therefore sea levels along coast lines differ in distance from the earth's center. The enormous mass of the Himalayas, for example, is stated by Tarr to pile up water to such an extent that the ocean surface is 300 feet higher at the head of the Bay of Bengal than at the southern tip of the peninsula of India. Winds also cause sea levels to vary, not only temporarily at a given place, as at times of hurricanes, but from place to place over long periods of time. Thus, according to Sverdrup, the trades produce a difference of 2 feet between the ocean levels on the Australian and American sides of the Pacific, along the equator. Similarly, there is a difference in ocean levels at the Atlantic and Pacific ends of the Panama Canal.

Movements of Ocean Water. Movements of the ocean water include waves, tides, and currents. Ordinary waves, caused by friction between winds and water over which they blow, sometimes attain a speed of 50 to 60 miles per hour and a height from trough to crest of as much as 40 to 50 feet, but usually both the speeds and heights are much less. In the southern oceans, where westerly winds blow without interruption by land masses, extreme wave lengths of 1500 feet from crest to crest have been observed, though normally they are 500 feet or less and, near shores, commonly under 25 feet. Among

other types of waves known, the more important are those resulting from great differences of atmospheric pressure, and those produced by some earthquakes. The former are common accompaniments of hurricanes, water often rising several feet and inundating low-lying coasts, as during the so-called Galveston "flood," at times of such storms. The latter occur when earthquakes affect the sea floor and the overlying water from top to bottom. In the open ocean, such waves are so broad and low as to be imperceptible but, on approaching shallower water alongshore, they pile up on the adjoining flat land, often causing great loss of life and property in densely populated regions. Fortunately, both hurricane and earthquake waves are of relatively infrequent occurrence.

Tides are caused by the attraction of the sun and the moon, with that of the latter more important because, though smaller, it is much nearer the earth. Distortion of the water surface of the earth by this attraction causes the hydrosphere to bulge on the sides of the earth toward and away from the moon; with depressions, low tides, between the elevations or high tides. The sun acts in similar fashion but, except when its pull coincides with that of the moon, its lesser attraction is obscured by that of the moon. When the sun and the moon act in conjunction, spring, or very high tides occur; when in opposition, very low, or neap tides. Thus tides, two high and two low, make their circuit of the earth each 24 hours and 52 minutes, as the earth rotates on its axis and the distortions of the ocean's surface shift location.

In the open ocean, the rise and fall of the tide is imperceptible, but along shores, and especially in V-shaped bays, the fluctuation is often great, as much as 30 to 53 feet in the Bay of Fundy, and slightly more in some of the Alaskan fiords. Where such great ranges occur, they interfere with the effective use of harbors and, similarly, when tidal currents develop, they handicap navigation. Normally, however, a moderate range of a few feet is advantageous in harbors, for it removes the wastes which accumulate along the waterfronts of great ports. Again, where tides invade the lower courses of rivers, for example in Tidewater Virginia, they tend to increase stream navigability. This was especially important in this particular area during the Colonial period, as noted in an earlier chapter. Tides are generally

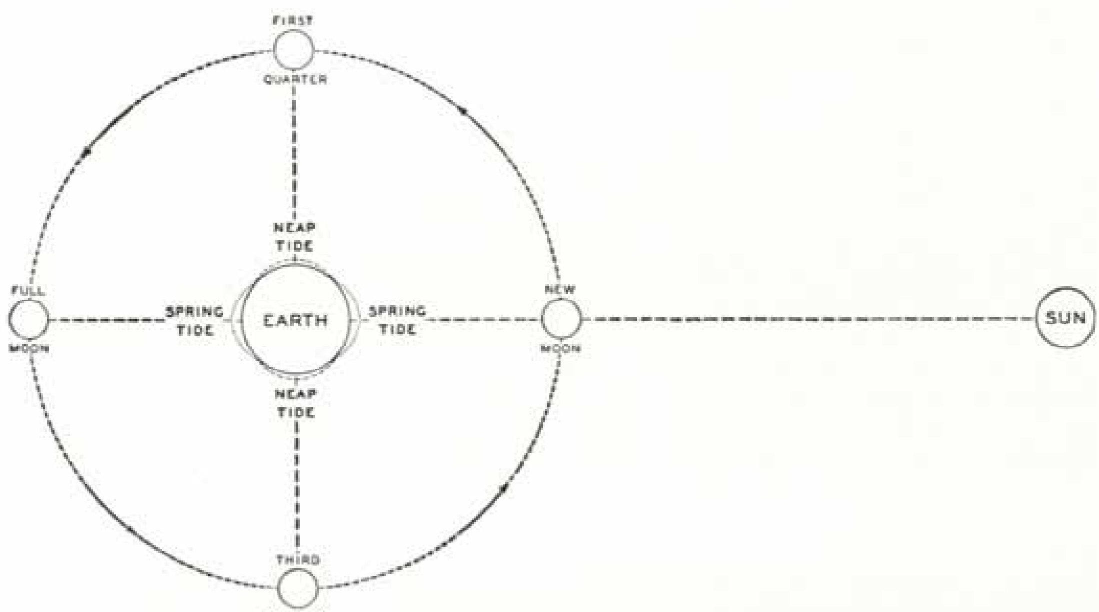

FIG. 219. When the attraction of the sun and the moon is exerted in conjunction, as at times of the new and full moon, spring tides, with high tides higher and low tides lower than the average, occur. At times of the first and third quarters of the moon, the attraction of the sun and moon are opposed to one another, which causes neap tides, with high tides lower and low tides higher than the average.

FIG. 220. Comparison of this map, showing the general paths of the great ocean currents, with Fig. 101, showing the generalized wind directions, will disclose a close correspondence between movements of the lower air and those of the surface waters of the ocean.

taken into account by mariners, in both entering and leaving harbors, because they affect channel depths and ease of navigation, especially if strong tidal currents develop. Tides also affect man by transporting and depositing sediment, sometimes blocking harbor entrances and thus necessitating dredging to maintain effective channel depths. Though man has long contemplated the possibility of harnessing them for development of power, use of the enormous amount of energy now wasted has so far proved economically impracticable.

Surface currents of the ocean waters, aside from tidal currents, are mainly wind-driven movements, with directions determined by prevailing winds, trends of coastlines, and the deflective influence of the earth's rotation. Thus, in the trade wind belts, the drift of the ocean water is westerly; in the belts of the westerlies, it is easterly; in monsoon areas in the Indian Ocean, the currents reverse direction with change of the seasons. The more important warm currents, the Gulf Stream of the North Atlantic and the Japan Stream, or Kuroshio, of the North Pacific, originate in tropical areas; cold currents like the Labrador Stream, in the polar oceans. Both affect life forms and man: marine life directly, by distributing oxygen and food; man, who uses marine life, indirectly. By their effect on ocean temperatures, they modify those over the land, particularly on windward coasts, toward which winds blow. Reference to a map of Europe will show the surprisingly high latitudes of the Scandinavian Peninsula which, though in large part as far north as southern Greenland, is much more habitable. This is not only because the climate is tempered by winds from off the water but by winds from over water which, though cold, is somewhat warmer than the average for such high latitudes. The effect of ocean currents on atmospheric moisture is illustrated off the coasts of Newfoundland and other areas where fogs are a result of the geographic distribution of warm and cold currents. Similarly, ocean currents affect both distribution and amount of precipitation, as on the west coast of the main island of Japan, where winds from over the relatively warm waters of the Kuroshio cause the winter maximum of precipitation and the heavy snows of the colder months. Space does not permit more detailed consideration of either the tides or currents, but additional discussion may be found in some of the selected references listed at the end of this chapter.

The Life of the Ocean. The ocean teems with life, both plant and animal, particularly alongshore, or wherever the water in shallow. This is also true in the surface layers of the open ocean

where light, necessary for plant life, penetrates. The types of life range from minute organisms making up plankton, in considerable part low forms of plant life, to the giant seaweed, kelp, which may attain a length of several hundred feet; and the animal life, from microscopic forms to whales, the largest present-day mammals. Both plants and animals are mostly of the lower orders. This is true for all plants of the open ocean. Among the animals, though even the higher divisions of the vertebrates are represented by the whale, seal, walrus, and others, and the reptiles by turtles and other forms, the invertebrates are most numerous, with fishes next. These life forms, either plant or animal, may be fixed, floating, or free-swimming. In all cases, they are more widely distributed than equivalent land life, partly because of the movement of ocean water, but more largely because of the greater uniformity of environmental conditions in the ocean than on the land. The most important factor limiting distribution of life forms in the sea is depth of the water. Therefore they may be considered in four subdivisions, based on that factor: (1) life of shallow and coastal waters; (2) life of the surface layers of the open ocean; (3) life of intermediate depths of the ocean; and (4) life at great depths in the ocean, this last of little economic importance.

Life of Coastal and Shallow Waters. Life forms of coastal and shallow waters are both abundant and varied in kind, the diversity resulting from differences in the character of coasts and bottoms, in temperatures, in salinity, and in oxygen and food supply. Conditions are especially favorable in tropical seas characterized by coral reefs, where many of the life forms are brilliantly colored. By contrast, the littoral life of higher latitudes and polar areas is extremely limited within the zone affected by shore ice, though abundant and varied farther from the land. Within individual zones determined by temperature, the amount and kind of life vary with the character of the bottom, the type of shore line, and the salinity of the water. Beaches and bottoms of coarse, shifting sand, or of gravel and larger rock fragments, are unfavorable for life; rocky coasts against which waves beat with great force permit no floating, but only fixed growths such as barnacles and seaweed; protected bays with bottoms of fine sand or clay support abundant life. There, the vegetation of the land and sea meet, as in the brackish waters of salt marshes and mangrove swamps.

Life of the Surface Waters. Plant and animal life of the surface waters, far from the land, is abundant. Some of the plants, algae and diatoms, are of microscopic size, whereas some of the seaweeds are large. The animals vary equally in size, from very small to forms as large as the whale. All, even seaweeds such as the Sargassum, are either floating or free-swimming forms, and all are widely distributed. Some float by means of air-filled cells; others by movement or swimming; still others are able to rise or sink by drawing in or expelling water from chambers, or by exertion of other muscular effort.

Life of the Intermediate Depths. Though less abundant than nearer the surface, life exists in the zone into which little light penetrates, far below the surface, but often even farther from the ocean floor. Though knowledge of the life of this zone is less complete than for that of the surface waters, it is known that certain animals such as deep-sea fishes, some blind and others with specially designed eyes, together with marine worms, crustaceans, and others, live in these waters.

Life of the Ocean Bottom. It is believed that even the ocean bottom far from shore is inhabited, the abundance of the life varying with temperature and oxygen supply. At great depths, however, where darkness is complete and pressures are very great, there are no green plants and the animals, both fixed and mobile, must depend on a rain of food from the densely inhabited surface waters. At these great depths, conditions are not only strikingly uniform, but they have remained essentially unchanged for thousands of years, indicated by the existence of life forms such as crinoids, formerly abundant elsewhere, but today found only as fossil remains in limestones and on the ocean bottom at great depths.

Interdependence of the Life Forms. Plant life provides the food supply for certain animals living in the ocean. Especially important in this respect are the unicellular algae and diatoms which help make up plankton. These minute organisms utilize inorganic matter, converting it into forms which can be used by the higher animals, many of which in their turn afford food for still others. Thus life in the crowded waters of the ocean, as elsewhere, is a continuous strug-

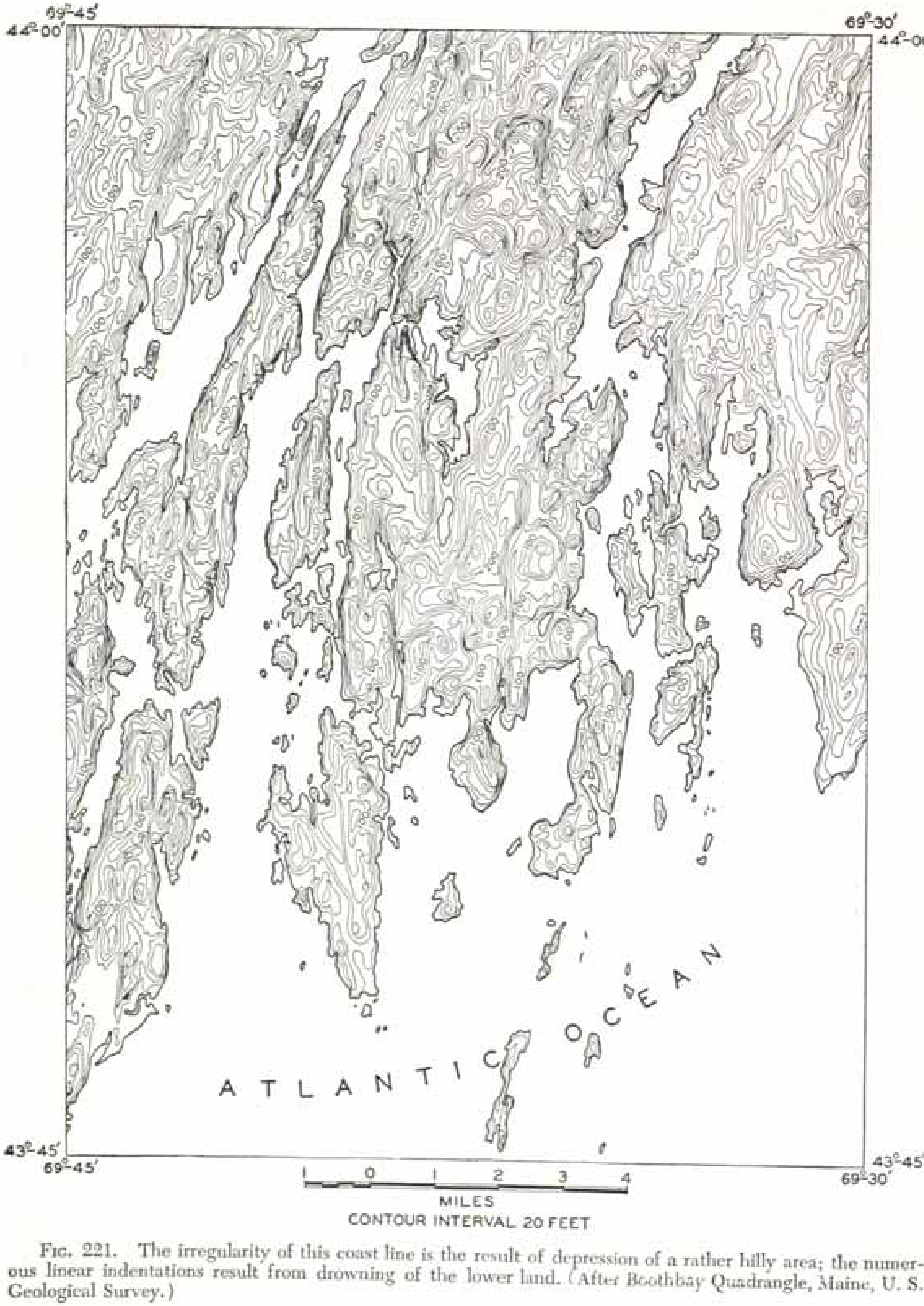

FIG. 221. The irregularity of this coast line is the result of depression of a rather hilly area; the numerous linear indentations result from drowning of the lower land. (After Boothbay Quadrangle, Maine, U. S. Geological Survey.)

gle for existence, with a natural balance maintained between life forms, excepting only that man, in his efforts to obtain a livelihood, may upset this balance, frequently to his disadvantage.

The Ocean Coasts. The seacoast presents a scene of continuous change. The erosive work of waves, ice, tides, and currents; sedimentation accompanying denudation of the adjacent land; activities of organisms; and, last but not least, crustal movement, either elevation or depression, make instability the rule where land and sea meet. The character of any individual coast line at any definite time will depend upon the activities of the agents mentioned as producing change; the type of shore line on which they operate; and the stage of its development. In its initial stage, a coast line may be either regular or irregular but, later, irregularities tend to disappear with wave attack on headlands and filling of indentations by sediment. Eventually, therefore, all coast lines become regular, except as they may be rejuvenated by uplift or depression.

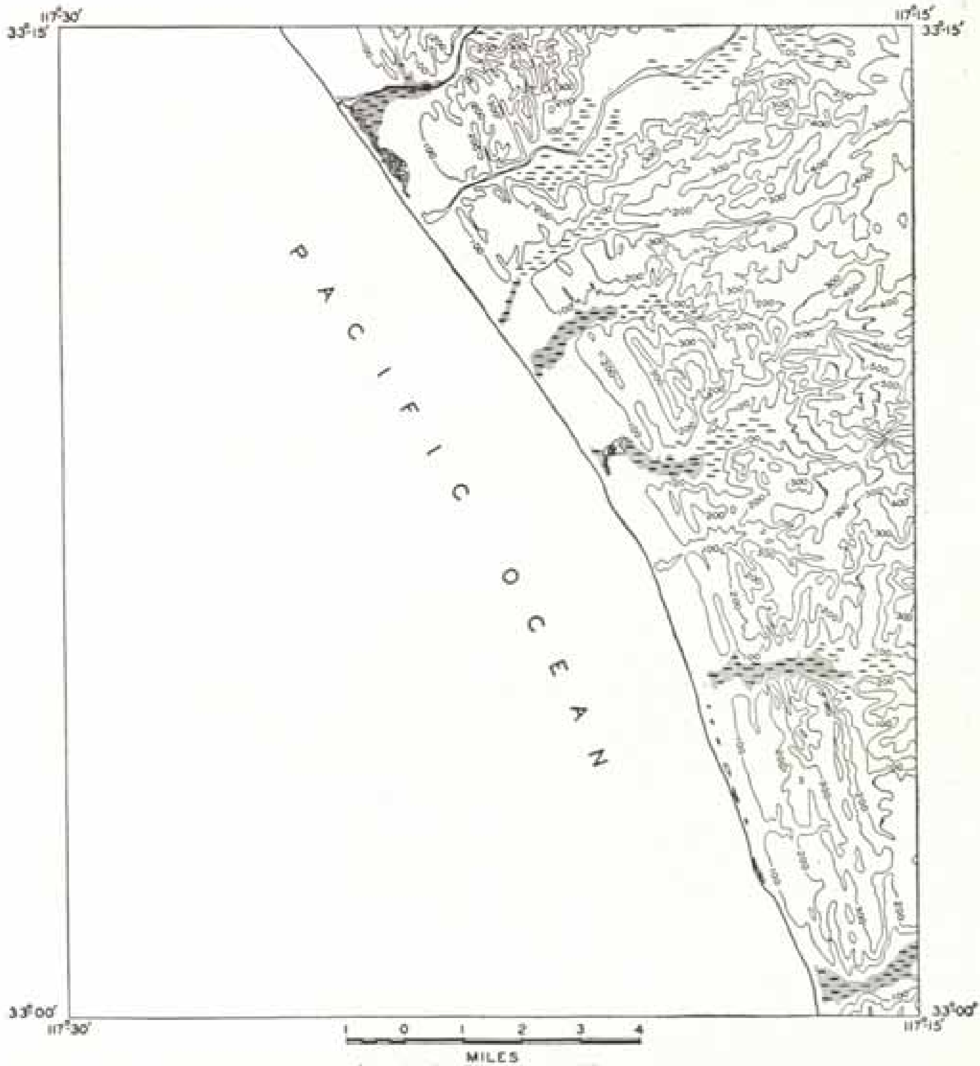

FIG. 222. This regular coast is the result of uplift which has exposed the flat ocean floor, thus forming a smooth coast line. (After the Oceanside Quadrangle, California, U. S. Geological Survey.)

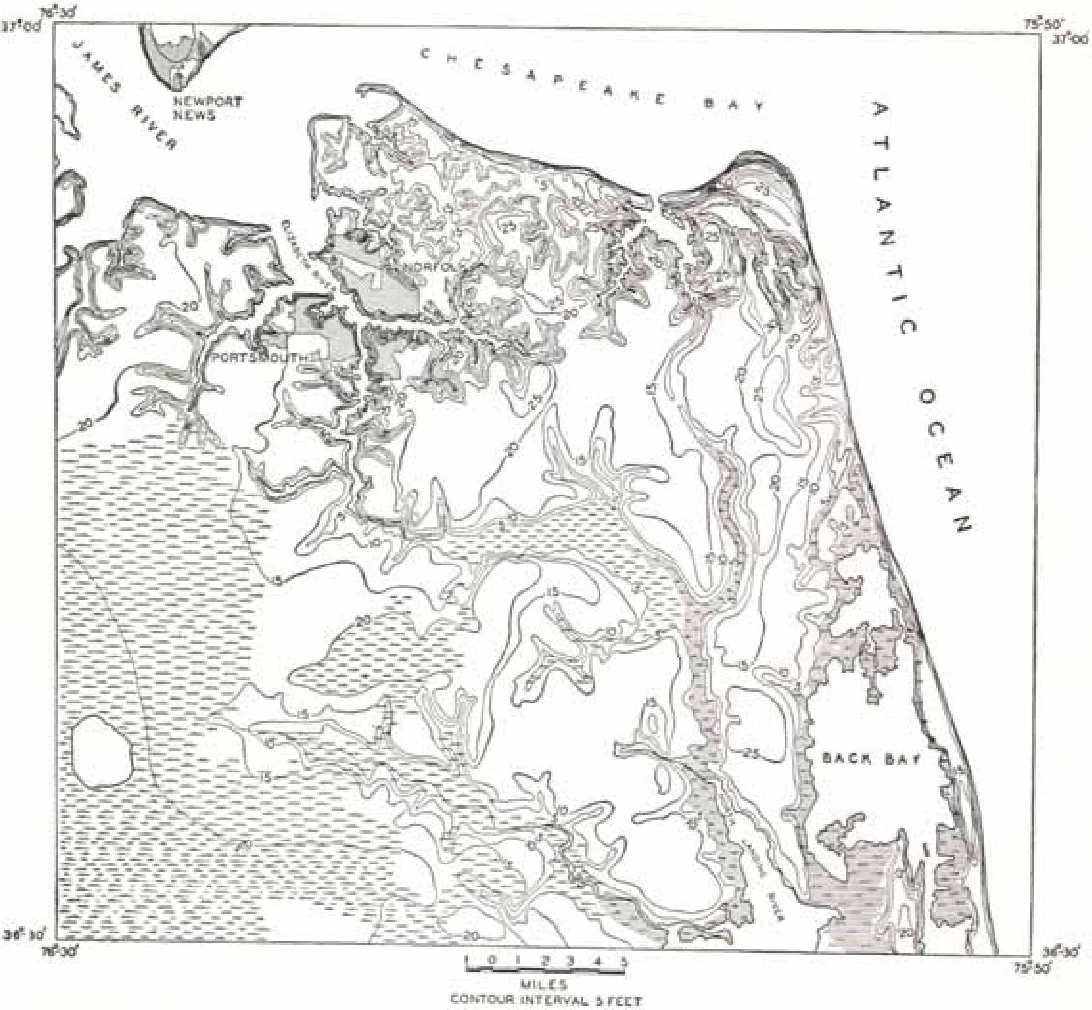

FIG. 223. The harbor of Norfolk, formed by local submergence and drowning of the lower courses of the James River and its tributaries. (After Norfolk Quadrangle, Virginia and North Carolina, U. S. Geological Survey.)

Effects of Depression or Drowning of the Land Surface on Coast Lines. The horizontal line of contact of land and sea, the datum plane or level from which elevations are measured, is known as "sea level." With either depression of the land surface below, or rise of the ocean water above this level, the sea invades the land to form a new shore line. The character of this will vary with the land surface. If the bordering land is of slight relief, or relatively flat, the new coast line will lack important indentations, except where large rivers enter the sea. Otherwise, it will be irregular, the exact degree of irregularity being determined by the topography of the adjoining land. Submergence of a plain of slight elevation, for example, will produce a moderately regular coast, with shallow bays resulting from drowning of the lower courses of the rivers and flooding of bordering flat land. Such is the condition of the Atlantic coast of Virginia and North Carolina. By contrast, submergence of rugged or mountainous land surfaces produces very irregular coast lines such as those of Norway and Alaska, with many deep, narrow, steep-sided arms of the sea, or fiords, penetrating the land for considerable distances.

Effects of Elevation and Mountain Formation on Coast Lines. Uplift exposes the sea bottom,

the topography of which determines the character of the new coast line. If uplift occurs bordering a plains area of slight relief, the new coast line will be regular, for sedimentation on the continental shelf adjoining such an area tends to erase irregularities of the sea floor. Such a coast affords few harbors and is difficult to approach because of the shallowness of the water offshore. Except in areas of local subsidence subsequent to uplift, as noted for Tidewater Virginia and North Carolina, this is the condition of much of the Atlantic coast south of New York City. Mountain uplift similarly tends to ensure a regular coast line, such as that of western South America, but, by contrast with conditions along the Atlantic and Gulf Coastal Plain of the United States, the water offshore is deep, for the ocean floor drops off abruptly.

Effects of Erosion and Sedimentation on Coast Lines. Everywhere along coasts, waves, tides, and currents cooperate to alter the outline of the shore. At the same time, rivers, wind, and other agencies of erosion contribute sediment, often in such amounts that it cannot be carried far from the land. Where this occurs, it is deposited as sand bars of various forms, or it may even form barrier beaches offshore, as well as shoal water alongshore to an extent to interfere with navigation.

Coast Lines Not Simple. Actually, few coasts are the result of either simple depression or uplift. Most have resulted from a complex series of changes of elevation, some local, others affecting extensive areas. Moreover, coast lines are also modified by local erosion and sedimentation, which produce marked differences in their character within short distances, as along the Pacific coast of the United States.

Harbors and Ports. Natural harbors are protected indentations of the shore line, or sheltered bodies of water where ships can anchor, secure from danger of storm. The larger number are the result of subsidence, but some are formed by uplift, and the exact form and depth of any may also reflect the operation of other agencies such as glaciation. The most important harbors, such as those of New York, San Francisco, and London, are formed by submergence of river valleys, though lagoons and similarly sheltered waters sometimes afford satisfactory anchorages. A good harbor is one of considerable size, adequately protected from storm, of sufficient but not too great depth of water to the shore line, with a moderate tidal range, and with a good bottom for anchorage. Further, it should be ice-free. It should also be connected with the sea by a straight, wide channel of adequate depth, not obstructed by sedimentation. Such a harbor will accommodate a large amount of shipping and the largest vessels satisfactorily. The moderate tidal range does not interfere with navigation and docking, yet debris is carried away and the water of the harbor is kept clean. Adequate depth near the shore allows vessels to dock and eliminates the necessity for lightering freight, and a satisfactory harbor depth and a good bottom permit vessels to lie securely anchored and safe, when winds are strong. Few harbors meet all these requirements, even measurably well. Many are too small or approaches are unsatisfactory, and dredging is often necessary to secure and maintain adequate depths. Others are closed by ice too many months of the year. In some cases, where coasts are regular, it may even be neces-

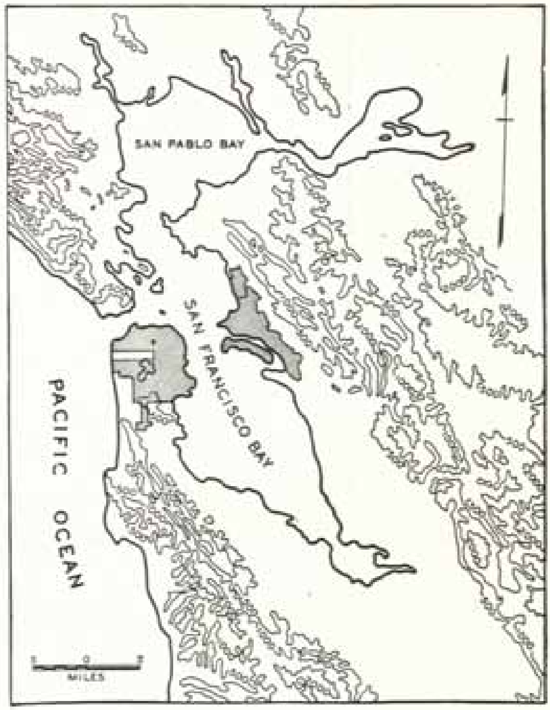

FIG. 224. San Francisco Bay, the harbor of the Bay Cities, was formed by local submergence and invasion of a break in the Coast Ranges by the waters of the ocean, which drowned the lower course of the Sacramento River.

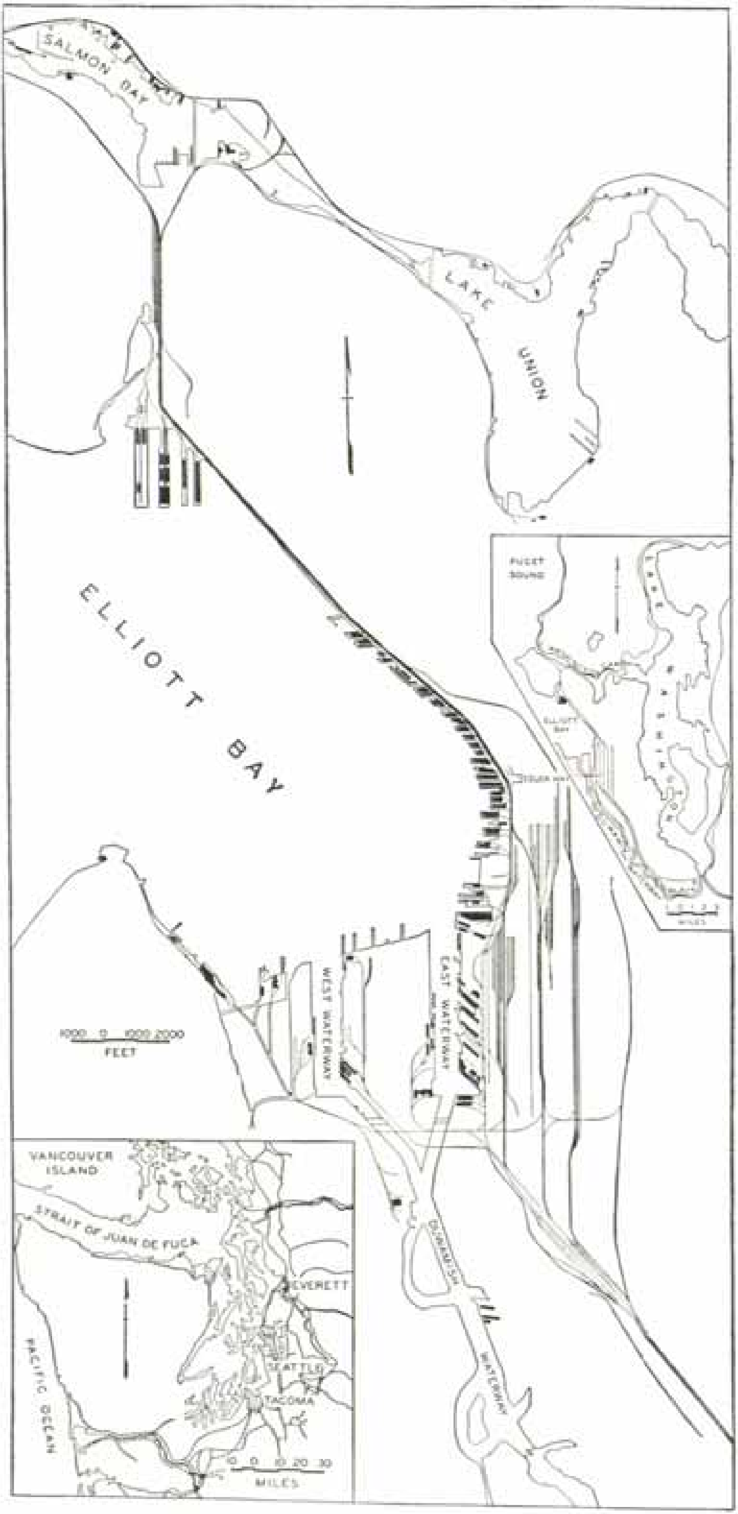

FIG. 225. The harbor and port of Seattle, Washington, on Elliott Bay. (After Port Series No. 7, Part I, U. S. Army Engineers.)

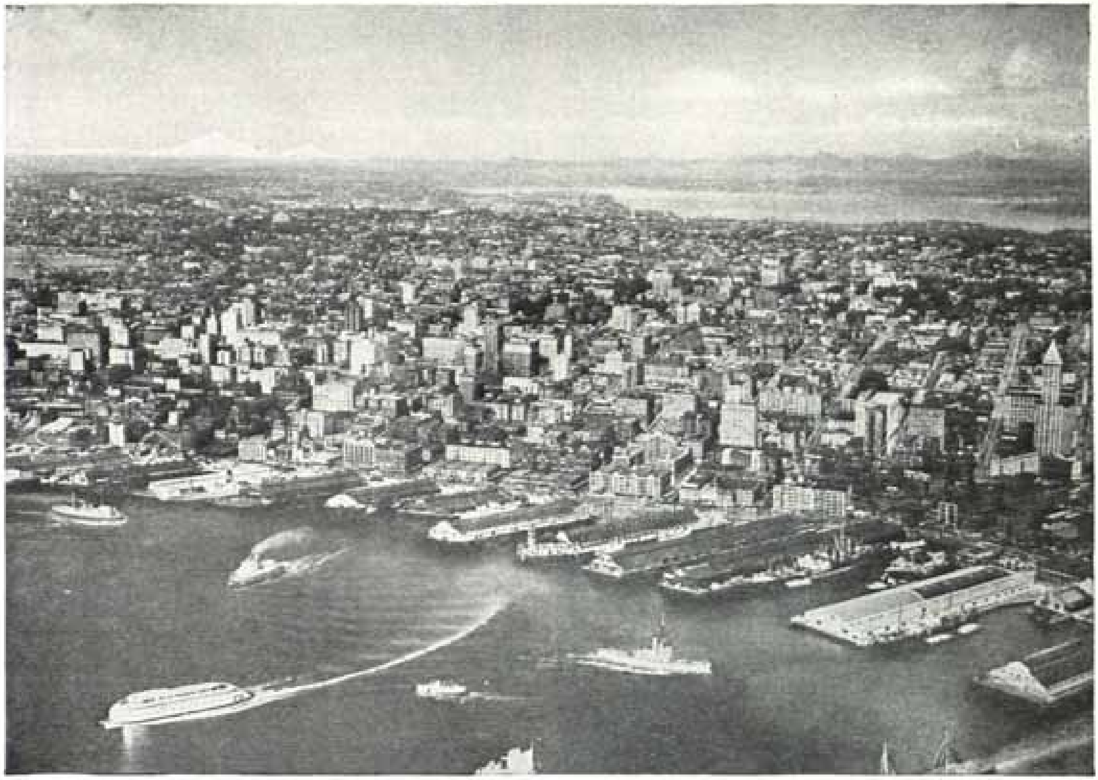

FIG. 226. Looking easterly across Elliott Bay and the city of Seattle, Washington. In the background is Lake Washington; and, beyond, the Cascade Mountains; to the left is part of Lake Union, connected with both Lake Washington and the Sound by canal. This gives both a fresh and a salt water harbor. This port is an important center for trade with Alaska and the Orient. (Courtesy of the Washington State Progress Commission.)

sary to construct artificial harbors, such as that of Madras.

A harbor may possess all or most of the desirable characteristics enumerated yet be of slight, if any, commercial importance, for it may be located where health conditions are poor or where no satisfactory city site is available. It may likewise lack adequate connection with the interior, or it may be unfavorably located with reference to highly developed areas which contribute freight. Again, it may not front on any of the oceans where the great trade routes of the world are located. Our important ports such as New York are therefore located: (1) where freight is available for shipment; and (2) where adequate though not necessarily ideal harbor facilities exist.

The Importance of the Oceans to Man. To those who live far removed from direct contact with the sea, the land which supplies so many immediate needs may appear important and the vast bodies of salt water, the oceans, which cover nearly three-quarters of the earth's surface, relatively unimportant, or even unnecessary. This erroneous belief, if entertained, illustrates the fact that the immediate and obvious is always more impressive than that which is remote, and therefore not apparent from direct, daily observation. In reality, the oceans are of fundamental importance to man in the following respects: (1) they affect climate, regulating temperatures and serving as the eventual source of our rainfall; (2) they have a considerable recreational value; and (3) their direct economic value as sources of food supply and minerals and for transportation is great. A favorable location with reference to the sea is, therefore, of vital importance to man.

The Climatic Effects of the Oceans. The oceans are regulators of land temperatures. Cooling slowly, they keep the land relatively warm in winter; heating slowly, cooler than it would otherwise be in summer, especially if winds blow toward the land. Their currents, carrying warm water from the tropics into high latitudes, and cold water from polar areas equatorward, modify temperatures in many latitudes. The regulatory action of the ocean on land temperatures is effected by means of winds. When they blow from over the water, the land is cooled in summer and warmed in winter. At Portland, Oregon, for example, with winds from over the ocean, winter temperatures are modified sufficiently so that it is possible to pick roses in bloom out of doors at Christmas, whereas at Portland, Maine, more than 125 miles farther south, the ground is commonly frozen and snow-covered at that time. In the interior, far from the coast, Christmas temperatures are normally even lower than on the east coast at Portland, Maine.

FIG. 227. On the beach at Miami, Florida, where a fortunate combination of climate and shore line serve as the basis for an important winter-resort industry. (Courtesy of the Miami News Service.)

Our rainfall is part of the cycle of movement of water from sea to land and back to the ocean from which it came. Carried inland by winds and precipitated as rain or in some other form, it starts return to its source, the ocean, to complete the circuit. This return may be direct for the portion which runs off, or it may involve several reevaporations and reprecipitations before it reaches its final destination, the sea, in part by way of air currents. At last, however, all except that fraction used by plants and locked up in chemical combination in plant tissues, that part which is combined chemically with constituents of the soil and rock, and the portion which finds its way into underground storage, returns rather rapidly to the sea. Where winds do not blow from water to land, or where and when air from over the ocean is not imported to the land, precipitation is small in amount and semiaridity to aridity may prevail. It is fortunate indeed that the continents are surrounded by oceans, which not only make land temperatures more equable but supply as well the water for life-giving rains.

Recreational and Health Values of the Sea and Its Coasts. The maximum effects of the ocean on temperatures are experienced on its immediate coasts. There, both extremes of dryness and actual temperatures are normally absent. In the tropics, the modifying effect of sea breezes on both actual and sensible temperatures is often important throughout the year, but, even in intermediate latitudes, thousands seek to escape the heat and discomfort of our large cities during the summer months by establishing temporary residence at the seashore. In many of these coastal areas to which summer or winter sojourners come, scenic beauty and fine beaches,

where both bathers and those who enjoy the sand may disport themselves, add to the attraction of the coast.

The Ocean and Food Supply. The abundant life of the sea, especially in littoral waters, affords a food supply for man. Thus fishing is the major support of the population of Newfoundland in normal times. It is also important in Japan, where it not only affords support for the fisherman but the principal "meat" supply for thousands who till the soil or work in stores and factories. Not only does the abundant marine life, both plant and animal, of the coastal waters present man with economic opportunity but, farther from shore, the life of the waters over the banks or shallows, such as those of the North Sea and off Newfoundland, and of the deeper waters of more remote polar seas, functions similarly.

The Mineral Resource of the Ocean. Every mineral occurring in the solid crust of the earth is found dissolved in sea water, though mostly in amounts so small that direct economical recovery is impossible. Despite the huge total of the dissolved mineral content, an average of 3½ per cent by weight of sea water, the only minerals extracted directly in important quantities at present are common salt and magnesium. In China and India, for example, much salt is manufactured in the coastal provinces by evaporation of sea water and the same is true in Mediterranean areas and, to a lesser extent, in the United States. In Germany, magnesium is also obtained from the ocean waters, and we shall probably draw on this source of supply to an increasing extent in the near future. Indirect recovery of other minerals by harvesting kelp, a seaweed which contains much potash, now carried on to a limited extent, may assume greater future importance if cheaper means of collection can be perfected.

The Oceans as Highways. The oceans connect the lands, serving as the highways over which moves most of the trade between the continents. This is true not only for the trade of an isolated continent such as Australia with other great land masses, but for that between the two Americas, and between Asia and Europe as well, where land connections exist. Trade between two countries in the same continent likewise moves in considerable part by sea under normal conditions, especially that in the bulkier commodities, for example, coal from Germany to Italy. Even trade within a given country, if the commodities take up much space or are of great weight but of low value per pound, and the distance they must move is considerable, may be carried by water, as from the Atlantic to the Pacific coast of the United States by way of the Panama Canal or, occasionally, by the even longer route around Cape Horn. Though this is the condition today, despite our extensive system of roads and rail lines, it was not true early in human history, even though land transportation was then slow, ineffective, and hazardous. At that time, oceans were barriers which man could pass, if at all, only with difficulty.

However diverse the theories as to the origin of man and the place of its occurrence, all agree that it was *on the land* and that, except as he might have been able to swim for short distances, the first man had no knowledge of how to move from place to place by water. How and exactly when he acquired this ability we do not know, thought it is probable that observation of floating reeds and logs suggested the possibility of their utilization as a means of transporting himself and his possessions. Great indeed must have been the elation of the individual who discovered that such crude craft could be propelled and their course directed by a stick or branch and, even better, that wind could be used to aid propulsion. Some of these earliest types of boats, progenitors of those of the present, are to be found today in northwestern Australia, where logs, pointed at both ends but not hollowed out, are still used to afford transportation by water. Even in China, many of the flat-bottomed sampans preserve distinct traces of their descent from a small raft of three timbers, with their ends upturned.

Man must have mastered the art of travel by water at a very early date for, as early as the Stone Age, he had boats, remains of which have been discovered in the Swiss lake dwellings and in the estuaries of England and Scotland, buried to depths of 25 feet or more. In Egypt, boats were known at least as early as 3000 B.C., and, at a comparably early date, in Babylon and other widely scattered areas, though their use for ocean voyages was more limited and of later occurrence.

In part this was because of the fact that, though direction could be determined by observation of the sun and stars, this was possible only in clear weather. Therefore it was for long desirable to keep the land in sight, and early navigation of

the sea was from headland to headland and largely confined to protected waters. The Chinese are supposed by many to have been the first to solve the problems of boat construction and to work out an art of navigation, followed, even today, without essential change or improvement. Not until after use of the magnetic needle or compass, late in the thirteenth or early in the fourteenth century, were voyages out of sight of land possible for the navigators of the Western world. The actual inauguration of navigation as we know it at present did not occur until the early fifteenth century, under the leadership of the Portuguese, who developed methods which have been improved to an extent that it is essentially an exact science.

Only during the past four and one-half centuries, therefore, have the oceans ceased to be barriers to the transfer of goods and the exchange of ideas. Not until after Columbus discovered America, for example, were maize, the potato, and tobacco known to Europeans, and many other parts of the world held similar surprises for their discoverers who arrived by water. Not only were the oceans long barriers to trade, but they likewise served to keep population in and invaders out, for early migrations and invasions were much simpler where no water barrier interposed. Thus, though both China and India suffered numerous invasions in the distant past, Japan was for many ears protected by her insular location, though this is not so true today. Similarly, we have witnessed the gradual lessening of the former effective barrier function of the Atlantic Ocean.

Man employs the sea for trade because ocean highways necessitate no expenditures for right of way, construction, or maintenance, except at the terminals. In addition, there are no heavy grades and a small amount of power will move huge tonnages of freight. Ships are also less expensive to construct than trains of the same capacity, and fewer men are needed for their operation. Again, hazards are commonly assumed to be fewer on the ocean than on the land. All these factors reduce costs of the water haul so that ocean transportation enjoys marked advantages over that by land.

To make these advantages of any importance, freight must be available in considerable volume, a condition which exists only on the borders of the great oceans where progressive and advanced populations live. This confines most of the great ocean trade routes to the North Atlantic and North Pacific oceans, particularly to the former at present. In the South Atlantic and South Pacific, the volume of trade is much less; in the Polar seas, it is virtually zero. The present relative importance of the oceans is, of course, subject to change, already in evidence in the increasing actual and relative importance of the ocean routes of the North Pacific.

Though probably less hazardous than land transportation, ocean shipping is faced with certain perils peculiar to the seas. Among the more important of these are violent storms, icebergs, fogs, and dangerous ledges and coasts. To counteract these hazards and minimize the dangers they introduce, the great maritime powers maintain weather bureaus which supply mariners with information concerning the weather, including the location, size, severity, and paths of storms, thus enabling owners and operators to take precautions which will eliminate unnecessary risks. In oceans where icebergs are of frequent occurrence in the shipping lanes, ice patrols are maintained to supply information as to their location, number, movement, and size, so that courses may be set intelligently. Here, radar can, and today does, play a part. In foggy weather, bell buoys and foghorns sound warnings which enable the mariner to steer a safe course. Protection from ledges is assured by adequate charts and lighthouses to indicate their location. Harbor entrances are mapped accurately; channels are marked to permit safe approach and departure; and dangerous coasts are protected in similar fashion. In some cases, pilots familiar with local waters are employed to direct navigation of the more dangerous portions of the course. With all these safeguards, travel by sea on modern cargo carriers and ocean liners is one of the safest means of transportation.

Before man attained his present stage of development, the oceans were much less important than they are today, when they are of such vital significance that interference with their proper function as carriers of trade brings great hardship, and even serious disaster, to large population groups. The oceans are today of importance to the world in much the same way that the circulatory system of the body is important to the individual, carrying the lifeblood of commerce, supplies necessary for existence, to popu-

FIG. 228. Pemaquid Point Lighthouse, east of Boothbay Harbor, on the highly indented, rocky coast of Maine. (Courtesy of the Maine Development Commission.)

lation groups. This expansion of the function of the oceans has revolutionized man's ways of life. Fruits from the Southern Hemisphere today appear in northern markets during the severest winter weather, yet we have only realized the beginnings of the possibilities as yet. To keep the ocean highways open is, therefore, essential for a continuation of progress.

In view of the importance of the oceans as highways, every nation has ambitions to control adequate coastal frontage for much the same reason the individual property owner desires to possess ownership of the means of access to, and egress from, his smaller landholding to the highways he uses in the course of his daily activities. In remaking the map of Europe at the close of the First World War, for example, the desirability of affording an outlet for the newly formed country of Poland was recognized by creation of the Polish Corridor to the Baltic, despite the inevitable risk of friction resulting from the splitting of German territory. All of the larger and more powerful nations have access to the sea; where their ambitions for such access have not been achieved completely, this has resulted from the conflicting interests of powerful population groups. Only a few of the smaller and relatively weak countries are cut off completely from the oceans and handicapped correspondingly.

Among the larger countries, however, the ocean frontage controlled differs considerably in both length and desirability. The U.S.S.R., for example, with a territorial extent of slightly more than 14.5 per cent of the earth's land surface before the late war, had an extended coast line, it is true, but largely on seas frozen much of the year. Therefore few of its harbors were open at all times, and these were so far from most of the producing areas that the effective flow of trade was hampered. To remedy this lack of adequate contact with the sea was impossible without alteration of existing national boundaries, or at least of national control of sea passages, a solution which would have met with opposition from those countries forced to relinquish territory or controls, and from other countries whose trade routes appeared to be jeopardized by such changes. Since the recent war, however, there has been some improvement of conditions so that, though still not ideal, they are much better than they were earlier in the century.

Canada, in latitudes comparable to those of the U.S.S.R., is similarly handicapped. The interior is far from seas unfrozen most of the

year, and lack of accessibility to ice-free ports on the east coast, toward which most of the grain moves, results in shipment of much wheat from Portland, Maine, when the St. Lawrence River is choked with ice during the winter months. By contrast, the 13,290,634 square miles of the British Dominions as a whole, approximately 24 per cent of the earth's land surface and supporting nearly 25 per cent of the world's population, are highly favored by coastal holdings in practically all latitudes. This is undoubtedly one of the factors contributing to the importance of British commerce in world trade. The United States is likewise fortunate in its frontage on unfrozen seas, and particularly favored because of its extensive coast line on the two great oceans which carry the major part of the world's seaborne commerce.

QUESTIONS AND EXERCISES

1. What is the comparative extent of land and water on the earth? The relative size of the different continents and oceans?
2. What is the continental shelf? What relation does it bear to the continents it borders? What forms its outer margin? What are the surface and topographic conditions on the continental shelf? What is the extent of the great ocean basins? The depth of their waters?
3. Why is the water of the ocean salt? How much mineral matter does the ocean contain? Why is common salt more abundant than calcium carbonate in ocean water? Why do the waters of seas differ in salinity?
4. What are the temperatures of ocean waters? Why are they so uniform? Within what limits do they vary? What causes these variations?
5. Describe conditions on the bottom of the great ocean basins. Why is the carbon dioxide content of the water so high at great depths in the ocean? What effect does this have on life?
6. Why does ocean level vary on different coasts? How great is this difference on the coasts of India?
7. What are the causes of waves? Which types of waves are most important? What causes ocean currents? What determines their paths? How do ocean currents affect the habitability of areas?
8. What causes tides in the ocean? Why are spring tides so high; neap tides so low? Of what importance are the tides to man?
9. Where is life most abundant in the ocean? How abundant and varied is this life? How does the life of the ocean differ from that of the land?
10. Describe the life of shallow and coastal waters. That of intermediate depths. That of the ocean bottom at great depths.
11. What are the agencies producing change along coast lines? Why do all coasts tend to become smooth in time?
12. What effect does depression of different types of coast have on coast lines?
13. What type of coast line usually results from elevation of the ocean bottom? Under what conditions will mountain formation produce an irregular coast line?
14. What is a harbor? How are harbors formed? Which of the types of harbors is most important?
15. What are the characteristics of a good harbor? Why is a moderate tidal range desirable in a harbor?
16. Under what conditions does a good harbor become an important port?
17. In what respects are the oceans important to man? How do they affect climate? How do they produce these effects? What minerals do the oceans contain? What minerals do they supply to man?
18. Discuss the importance of the oceans as highways. Why are they more important for such use today than earlier in human history? How old is ocean navigation?
19. What advantages does ocean transportation have over that by land?
20. Why do nations strive for adequate contact with the sea? Why do some nations lack such access to the sea and others have only inadequate frontage? Why is it difficult to remedy this lack? In what respects has the U.S.S.R. improved her access to the sea recently? In what respects, if any, is this struggle for access to the sea playing a part in current world happenings?

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Tarr, R. S., and Martin, L., *College Physiography*, The Macmillan Company, New York, 1914, Chaps. XIX, XX, XXI.

These three chapters contain an elaboration of the text discussion of the oceans, their life, and the movements of their waters.

Chapter Twenty-Six

LIFE FORMS: PLANT AND ANIMAL

Environment and Life Forms. Each factor of the physical environment is modified by its interaction with others. Climate affects and is affected by land forms; soils reflect the influence of both. Similarly, the natural vegetation of an area represents an accommodation to several environmental factors, generally those of the present, though occasional relict types may persist temporarily, even in the face of competition of other forms better suited to present conditions. These relict "plant communities," or groups of plants, may maintain their hold on an area for some time, largely because, with plants as with man, possession is "nine points of the law," though competition, the "tenth point," will eventually dispossess them.

Capture of any area by certain plant communities is not permanent, for not only do climatic, drainage, and topographic changes, occurring over long periods of time, cause modification of the natural vegetation, but the vegetation itself produces changed conditions, often over relatively short periods of time, which cause one plant community to succeed another, irrespective of the operation of other agencies. Thus change is the rule in plant life, with such balances as are attained at any moment only temporary episodes in the total life history of the flora of an area.

In view of the fact that types of vegetation reflect climatic, topographic, soil, and drainage conditions, the natural vegetation, or the complex of plants typical of an area, affords an indication of the general characteristics of the environment as a whole, with local departures from the general character of the flora representing responses to minor variations within the area. In this discussion of natural vegetation, the objective will be to establish the basis for the geographic distribution of the major types only, in terms of environmental factors.

Climatic Conditions and Natural Vegetation. The range of any species of plant is restricted by climate, but since most plants are tolerant of considerable departures from the optimum, or most favorable condition for their growth, the natural vegetation of an area affords only a general picture of its climate. This is true not only as regards temperature and moisture conditions, the most important of the climatic elements affecting vegetation, but for those of lesser importance as well.

For any given species of plant there is a certain temperature range within which its existence is possible, with an optimum which ensures most vigorous growth. Fortunately, these ranges and optima differ greatly for plant species so that, for all parts of the earth's surface not covered at all times with snow and ice, temperature conditions alone do not exclude the possibility of a vegetation cover of some sort.

Where temperatures are high throughout the year, and other conditions are likewise favorable, plant growth may be continuous; where the frost-free season is limited in length, plants must accommodate themselves to the shorter period available for growth. This may be accomplished in a variety of ways. With annuals, or plants which grow and mature during the warm season of one year, a seed or some other structure which will reproduce the species is perfected to tide over that portion of the year during which normal vegetative growth is impossible and the plant itself dies. With perennials, or plants which live over a period of years, a resting stage, during which growth ceases and most vital life processes are retarded or possibly even cease completely, may afford solution of the problem of existence

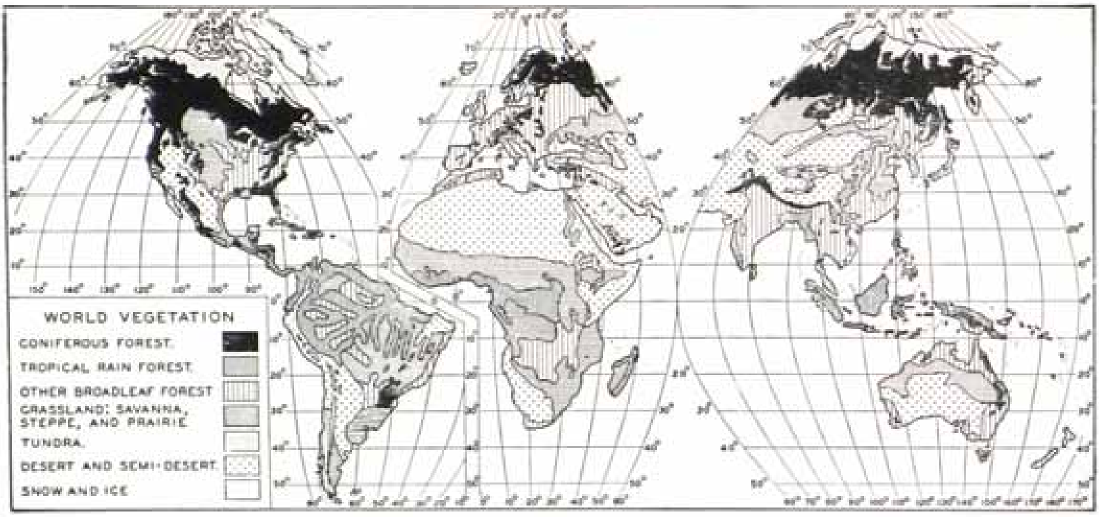

FIG. 229. Distribution of plant communities for the world. This map is highly generalized, for the scale on which it is drawn does not permit showing detail effectively. (After the U. S. Forest Service and others.)

during the cold months. This may be marked among herbaceous plants by death of the portion above ground; among woody plants, or shrubs and trees, by shedding of leaves. Among the cone-bearing trees with needlelike leaves, though an adjustment to low temperatures occurs, it does not have any such easily observable manifestation and therefore passes unnoticed by the average person.

Sunlight is necessary for the growth of all green plants, or those which use inorganic constituents of the soil and air as raw materials from which to produce organic matter such as sugar and starch. These serve both to promote vegetative growth and for storage in seeds or some other plant structure designed to reproduce the species. In many areas in high latitudes, where the frost-free season is often so short that plant life might seem impossible, this handicap is offset by very long daylight periods, sometimes of several weeks in length, so that plant growth speeds up sufficiently to allow completion of the life cycle in a surprisingly small number of days. Thus the necessary length of the vegetative season of a plant species is affected by the length of the daylight period and the percentage of the possible hours of sunshine during that period.

All plants need water, but the amount required varies with the species. Some with low water requirements are able to grow in deserts; others are adapted to swamp conditions; still others grow on well-watered uplands, each showing by its appearance and structure the moisture conditions favorable for its occurrence. Where water supply is ample throughout the year, plant growth may be continuous if temperature and other conditions are favorable, but where such is not the case, plants must accommodate themselves to this variation in the supply of available water. In the tropics, this is often accomplished by perfection of structures which check evaporation, and by shedding of leaves; in intermediate latitudes, where the lower temperatures, especially during the colder months, reduce the rate of evaporation sufficiently, shedding of leaves alone may be sufficient.

Soils and Natural Vegetation. Responses of plants to climatic conditions are general, but those to soils are specific. Thus, *within an area* characterized by the same general type of vegetation, such as an upland hardwood forest, the distribution of definite species is normally an accommodation to soils. Scrub oak, for example, will be confined to sandy areas; white oak will occupy better soils. Similarly, in areas of coniferous forest, jack pine will preempt poor, sandy soils; white pine, those which are more desirable. In the drier and generally treeless areas, where concentration of soluble mineral matter in the surface layers of the soil is often considerable, the

effect of soils in determining the exact species of herbaceous or brushy vegetation is especially marked, since tolerance of salt and alkaline matter is highly important in deciding the character of the limited vegetation of these dry areas. In very high latitudes, as well, where the soils are high in organic content and generally strongly acid, this characteristic limits vegetation to a few types of plants which grow effectively under such conditions.

Plant Communities. Because of tolerance of plants for a considerable departure from optimum climatic conditions, variable with the species, it follows that several types of plants will find an area more or less satisfactory for their existence. Those whose requirements are met most effectively will be dominant; others will be present in lesser numbers. Such a *group* of plants, adapted to the physical conditions of an area, made up as it is of many individual species, is known as a "plant community."

In our consideration of plant communities, we shall recognize only four major groups, some with two or more subdivisions, though a complete, detailed classification would necessitate recognition of many more subtypes. The four major communities recognized and described briefly in the following pages are: (1) forest communities, (2) grassland communities, (3) semidesert and desert communities, and (4) polar communities.

Trees dominate the forest communities, with other woody plants of secondary importance. Such grasses and other herbaceous growths as may be present are of only limited significance.

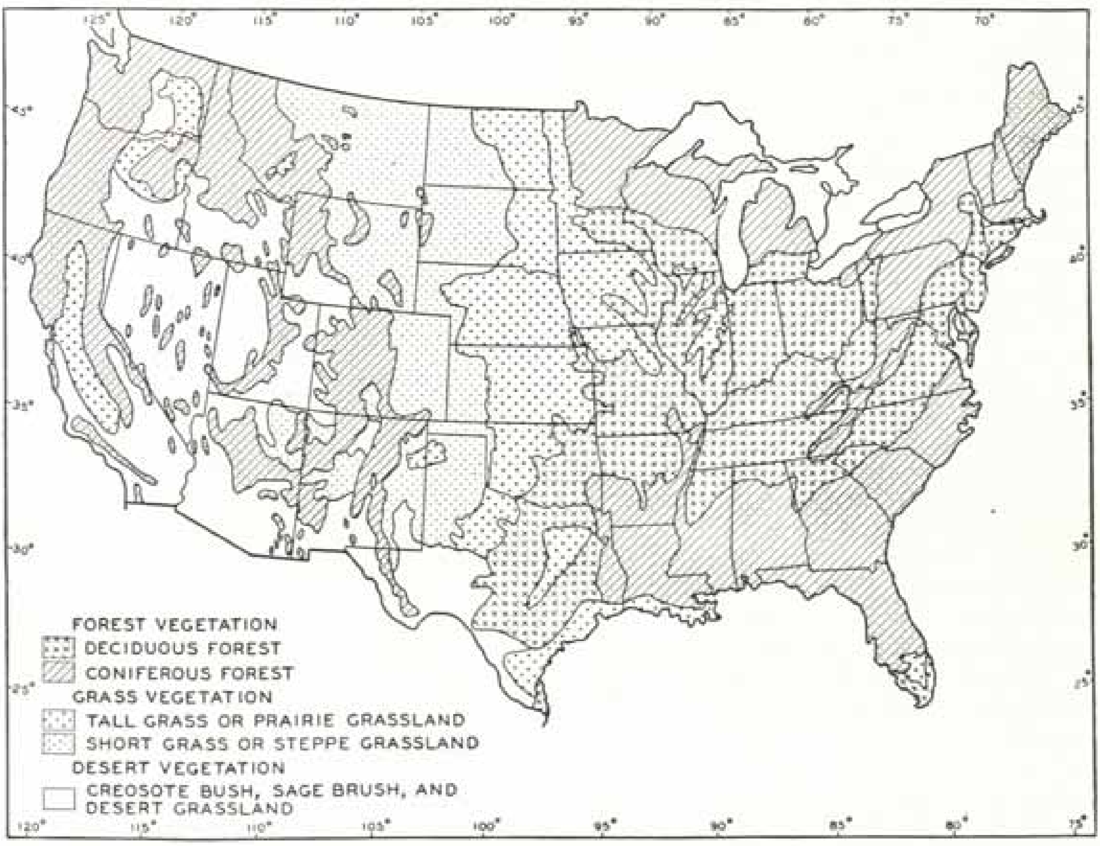

FIG. 230. Distribution of plant communities in the United States. The change from one type of forest to another is not as abrupt as might be inferred from the map. Northern hardwoods give way by gradual stages to conifers; southern conifers to mixed stands and pure hardwoods. Similarly, grasslands of different types merge into one another gradually. This is likewise true for the vegetation types shown in Fig. 229. (After the U. S. Forest Service and others.)

Where best developed, in the true forest, tree growth may be so vigorous as to exclude practically all other forms; where conditions are somewhat less favorable, brushy growths may assume considerable importance and even tall grasses may capture an appreciable fraction of the surface. In areas of fair to abundant rainfall, the forest competes with grassland communities for possession, preemption by forest occurring where rainfall, in association with high temperatures, is abundant; grassland communities assume dominance in the drier areas.

In grassland communities the typical vegetation is grass, perennial rather than annual, with other herbaceous growths of less importance. Trees, if present, are few in number, scattered, and confined to the wetter stream margins. Grassland areas in the tropics are often termed "savannas"; in intermediate latitudes, "steppes," this name likewise being quite generally applied to all short-grass areas, irrespective of the latitude in which they occur. Prairies, found only in well-watered regions and characterized by tall grasses, are generally assumed to be occupied by plant communities which have not been displaced by forest, often because of man's interference with the natural pattern of distribution of vegetation.

Desert and semidesert communities, comprising both herbaceous and woody plants, are found only in dry regions such as the Sahara. The species making up these communities must have special adaptations to overcome the handicap of a small supply of water.

Polar communities are composed of plants adapted not only to the rigors of the long, cold winters of very high latitudes and the low temperatures of high altitudes, but also able to maintain existence with a small amount of water, for precipitation in all cold regions is light and water is largely locked up in the form of snow and ice, and hence not available for plant use. In many essential respects, therefore, the vegetation of such communities bears a rather close resemblance to that of desert areas.

Though recognition of the plant communities mentioned is useful in picturing the geographic distribution of natural vegetation, definite demarcation of the limits of each is impossible, since one community merges gradually into another. For example, forest may merge into grassland through a parklike intervening belt, and grassland may pass imperceptibly into bordering deserts. This absence of sharp boundaries results from the considerable tolerance of individual plant species for varied climatic conditions, a fact which has been pointed out earlier.

Forests and Forest Types. Forests require much water. Therefore their occurence is limited to those regions where rainfall is heavy enough to maintain an adequate supply of moisture in the subsoil, even during those periods when precipitation is temporarily deficient. Strong winds, low relative humidity, and other conditions which facilitate evaporation unduly are unfavorable for trees. The exact forest community of any particular forested area is determined by the type and amount of variation from the optimum, within the fixed climatic and other limitations for effective tree growth.

Evergreen Hardwood Forests. Evergreen hardwood forest communities occur at low altitudes in the tropics and on their margins, where rainfall is heavy and well distributed throughout the year. Because of absence of either a dry or a cold season, shedding of leaves is gradual and trees are never bare. Therefore this is an *evergreen* forest. It is likewise a *hardwood* forest, for the trees do not have needlelike leaves, as do the conifers. Many of these tropical hardwood trees also have dense, hard wood, but this is not the reason they are known as *hardwoods.* In fact, some of the tropical hardwods have soft wood. Climatic conditions are optimum for tree growth in these forests, hence the vegetation is very luxuriant, and especially so in the tropical rain forests of the doldrum belt and of windward coasts where trade winds blow, if these coasts are backed by highland barriers. The stand is extremely varied in kind because many species of trees find the climatic conditions favorable. The trees are both of large circumference and tall, with an occasional forest giant towering to heights of as much as 175 feet, rising 75 feet or more above the general upper level of the forest of which it is a part. Since abundant rainfall keeps the soil continually moist, it is unnecessary for tree roots to penetrate to great depths to secure water. Therefore they spread out at or near the surface, tree trunks expanding at their bases into great buttresslike, and even stiltlike, roots. The dense canopy of leaves overhead shuts out light, but the lower levels of the forest are nevertheless a tangle of vines or lianas which, supported

FIG. 231. *Top:* Tropical rain forest of southern Nigeria, Africa. To the right and left, the forest is unbroken but, in the foreground where light reaches the ground, there is much small growth.

Bottom: A waterway choked with vegetation in the drainage of the Rio Negro, Brazil. In the foreground are the great pads of the *Victoria regia*, several feet in diameter; in the background, the growth is so dense that passage by boat is difficult. (Courtesy of Theodor Benzinger.)

by the trees to which they cling, spread out their leaves at the higher levels where light is present. On the branches of the trees, smaller herbaceous plants such as orchids find a foothold and likewise a place in the sun. Everywhere is a luxuriance of vegetation unmatched elsewhere in the world, for nowhere else are conditions so favorable for rapid and varied plant growth. In slightly higher latitudes, on the margins of the tropics where the climate is somewhat less favorable, vegetation is much less exuberant, though the general character of the forest may be much the same as nearer the equator.

Deciduous Hardwood Forests. In those parts of the tropics where seasonal deficiency of precipitation causes plants to develop means of checking evaporation during the dry season, trees shed either all or part of their leaves. Because of this fact, such a forest is said to be "semideciduous" or "deciduous," dependent on the percentage of the leaves lost. In intermediate latitudes, long, cold winters will likewise cause trees to drop their leaves as a means of checking loss of water when the ground is frozen, and the amount of water available in the soil is inadequate to permit the evaporation possible if the leaves were retained. Most of the hardwood forest of intermediate latitudes is, therefore, deciduous in type. The trees are also adapted to climatic conditions by having relatively thick bark, which checks loss of water, necessary during the colder months, but large, thin leaves which facilitate evapora-

FIG. 232. A virgin stand of beech in a deciduous hardwood forest. Big Ivy District, Pisgah National Forest, North Carolina. (Courtesy of the U. S. Forest Service.)

FIG. 233. Palm and thorn forest, Tanganyika, Africa. (Courtesy of Theodor Benzinger.)

tion during the warm season, when water is available. Small herbaceous, woody, and brushy growths are common where the floors of these forests are reached by ample light. Stands are not so varied as in the rain forest, that is, there are fewer species than in the evergreen hardwood forests of the lower latitudes, one or more being dominant, for example, oaks in an oak forest; oak and hickory in an oak-hickory forest; and beech in a beech forest. Other species, though present, are of only secondary importance. This is very different from conditions in the evergreen hardwood forests of the tropics, where no single species of tree is sufficiently important to impose its name on the forest community.

Scrub and Thorn Forests. These vary in composition from scattered woody growths competing with grasses and other herbaceous plants to dense stands of small, often thorny trees and other plants. Trees of such forests in the tropics are never large, seldom exceeding 1 foot in diameter, and they are generally deciduous, unless the amount of leaf surface exposed is exceedingly small. In the tropics, such forests occur in and on the margins of the savanna grasslands.

In California, in Mediterranean areas of the Old World, and in other regions with a similar climate, the forest is likewise scrub at the lower elevations, but the trees do not shed all their leaves at any one time, protection from excessive evaporation being secured by reduction of leaf surface, by development of thick, leathery, hard-surfaced leaves, and sometimes, though not characteristically, by thick, corky layers on the branches and trunks of the trees.

Coniferous Forests. Cone-bearing species or conifers give identity to these forest communities. The trees composing their stand contain much resin and most of them have needle-shaped leaves which are retained for several years and shed

FIG. 234. An open stand of oak on the lower slopes of the better watered canyon at the right merges into two types of brushy growth, locally known as "chaparral", Santa Lucia Mountains, Monterey County, California. The brushy growths on the upper slopes are dense thickets of chamiso; at the lower left, these are replaced by a tangle of manzanita. (Courtesy of W. S. Cooper.)

gradually, so that the forest remains green throughout the year. In forests of this type, the amount of small growth on the floor varies with the subtype. In the great redwood forests of northern California, the serried ranks of giant trees may rise from a floor carpeted with needles, often with almost no small growth; in the Douglas fir forests of the Puget Sound region, great ferns as tall as a man and much undergrowth are normally present. Similar contrasts exist between coniferous forests in other areas. In the southeastern United States, for example, the stand is commonly open and the ground between the trees is covered with grass and brush; in virgin timber in the Lake States, much of the forest floor is bare of vegetation or, at most, covered by limited amounts of brushy undergrowth. Coniferous forests, composed of different species, extend from lower middle latitudes to the subarctic, where they are given the name of "taiga" in Siberia. They likewise occur not only at sea level in the latitudes mentioned, but also at elevations over a somewhat greater north-south range.

Coniferous Forests of Middle Latitudes. These are the most valuable of our commercial forests, supplying most of our lumber for construction and pulp for paper manufacture, for white and longleaf pine, Douglas fir, redwood, and spruce are suited to those uses. Moreover, the trees attain considerable and often great size. Further, many of these forests are close to markets. In the eastern United States, most of the commercially exploitable stand has been cut; on the Pacific coast, much still remains. Where lumbering operations have been extensive, despoilation of the forest has given rise to a serious problem of effective use of the cutover land, much of which does not lend itself to profitable agricultural use.

Coniferous Forests of the Subarctic. These merge with steppe grassland or the coniferous and hardwood forests of middle latitudes on their equatorward margin, and give way gradually in the higher latitudes to tundra or frozen swamps, where climatic and other unfavorable conditions prevent tree growth. Conifers such as larch or tamarack, spruce, fir, and others predominate, though there is a sprinkling of deciduous trees such as alders and willows in damp areas, and of

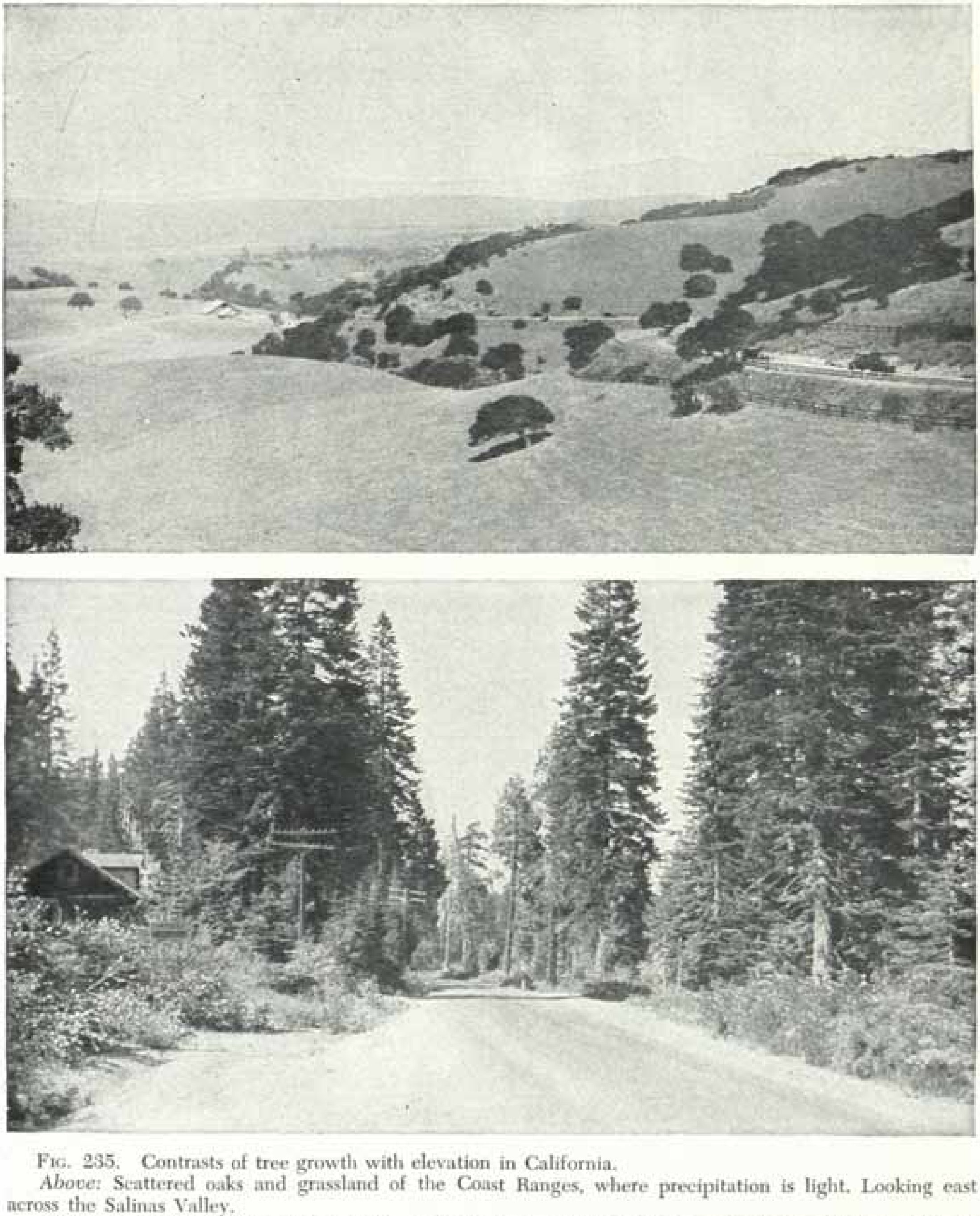

FIG. 235. Contrasts of tree growth with elevation in California.

Above: Scattered oaks and grassland of the Coast Ranges, where precipitation is light. Looking east across the Salinas Valley.

Below: Coniferous forest of the Sierras, west of Lake Tahoe in the Sierras, where rainfall is ample in amount.

aspen, birch, mountain ash, and others, where lumbering has occurred and fires have run, or where natural drainage is somewhat better. In these higher latitudes, though precipitation is light, soils remain moist and decay is slow. The floor of the upland coniferous forest is therefore

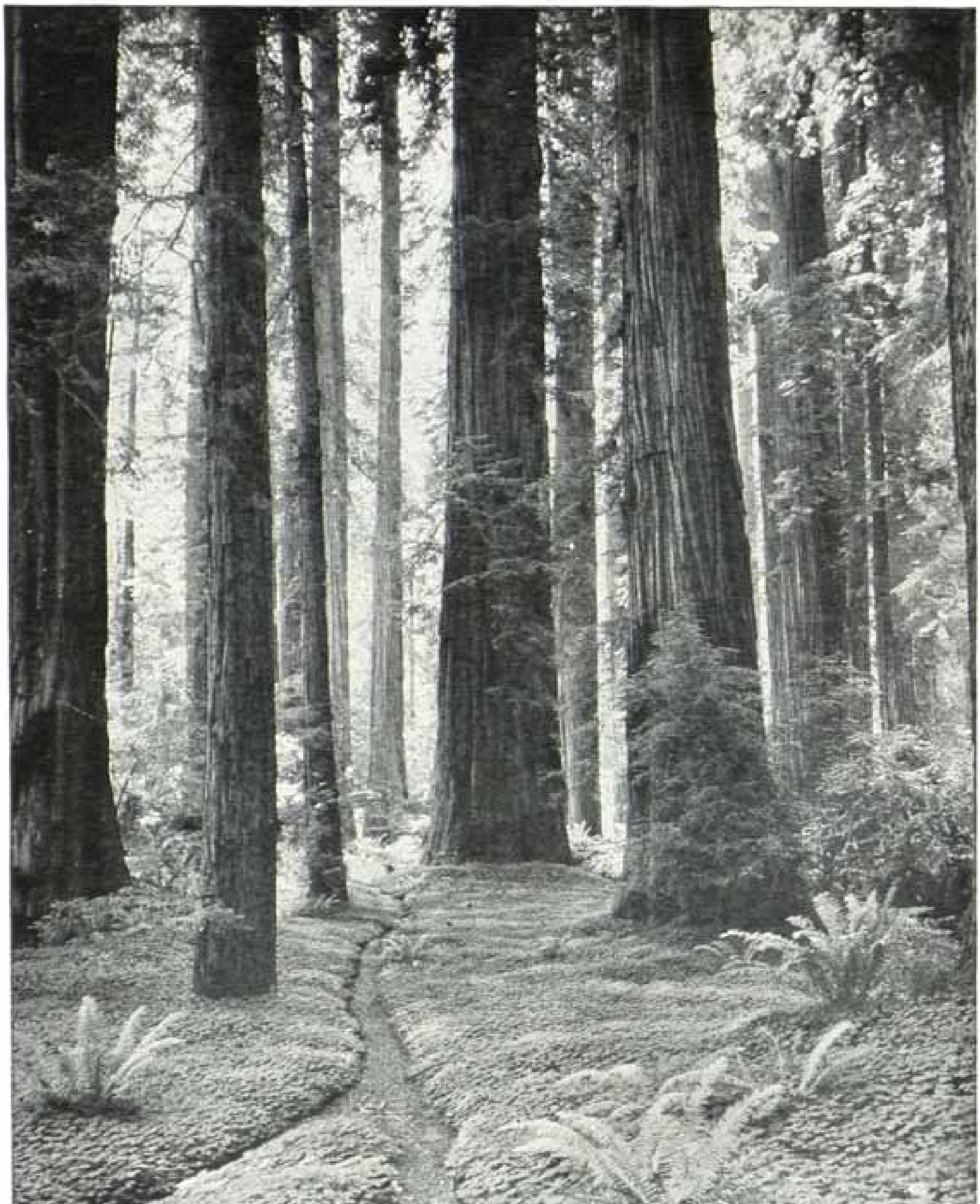

FIG. 236. A forest of giant redwoods in northern California, with comparatively little undergrowth. In some cases, even this small amount is lacking and the ground is carpeted to a depth of several inches with needles. These forests are very impressive. On all sides tower the huge columnar trunks of the enormous trees; no wind disturbs the lower levels; and almost absolute silence prevails in the semitwilight, even when one walks over the thick carpet of needles. (Courtesy of the Redwood Empire Association.)

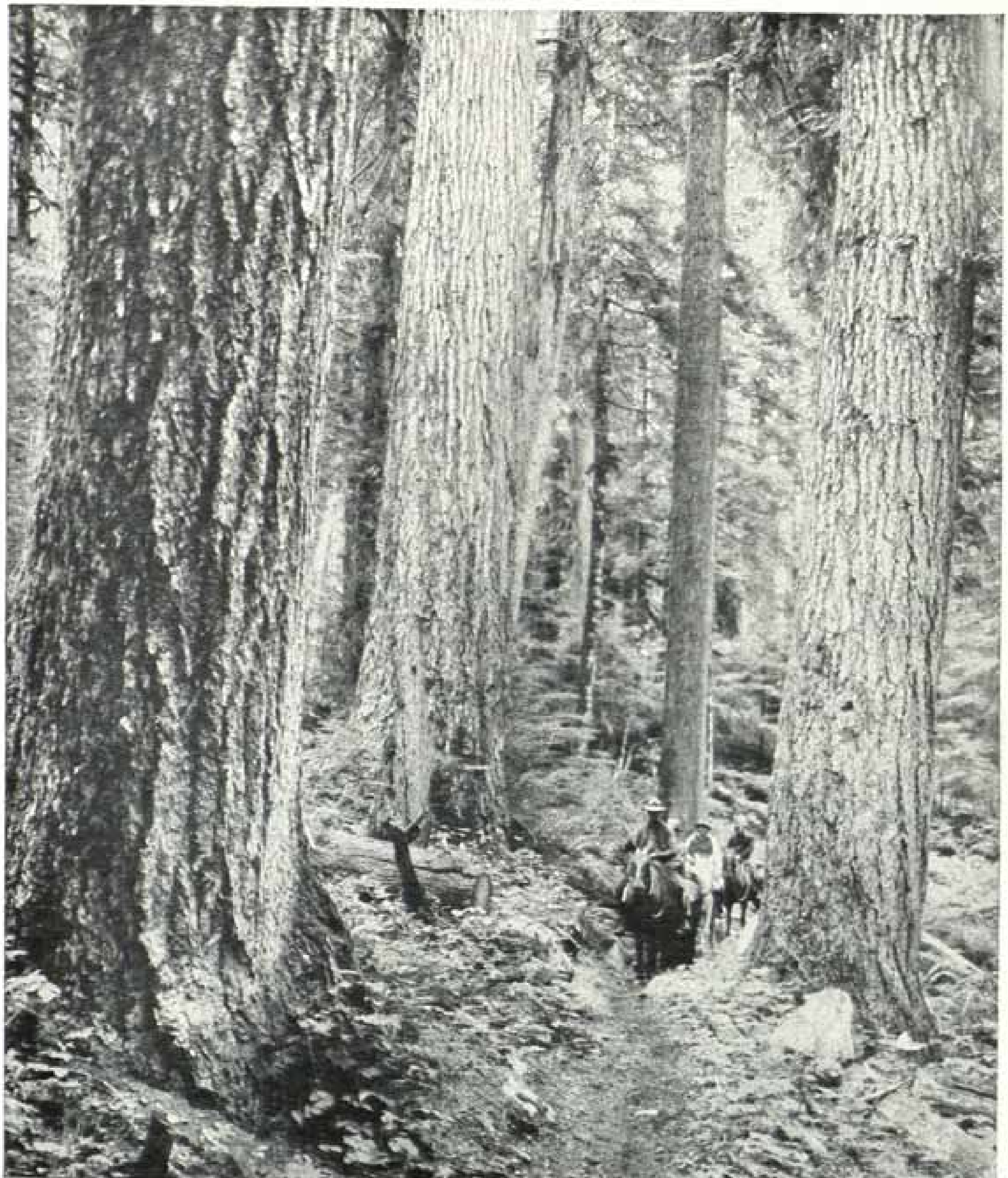

FIG. 237. A Puget Sound forest of Douglas fir in western Washington. The forest is dense and many of the trees are large, but there is also much small growth. This is the most important of the commercial forests of the United States. (Courtesy of the Washington State Progress Commission.)

blanketed with a layer of slowly decomposing needles which smothers all small growth; in the flat, poorly drained areas of spruce and other forested swamp, the ground is covered with sphagnum moss. The growth period of these forests is limited by the short summers, the water in the ground being locked up in the form of ice during the winter months when temperatures are

consistently low. With this short frost-free season, associated with other unfavorable conditions, growth is slow, trees are small, and this and the species present make the forest more valuable as a source of pulpwood than for lumber.

Swamp Forests. The character of swamp-forest growth is affected by wet soils, for not all species of trees thrive where soils are waterlogged and poorly aerated. Thus, in the brackish waters of the coastal swamps of central and south Florida, mangrove makes up much of the growth; on the overflowed, wet, alluvial areas of the South, cypress, gum, and swamp oaks are among the commoner species; in swamp areas of higher latitudes, trees such as larch, or tamarack, and swamp spruce replace the species characteristic of the lower latitudes. Of these trees, the oaks and gums are hardwoods; the cypress, larch, and spruce are conifers. In part, they are deciduous, as larch and cypress; in part they retain their leaves through-

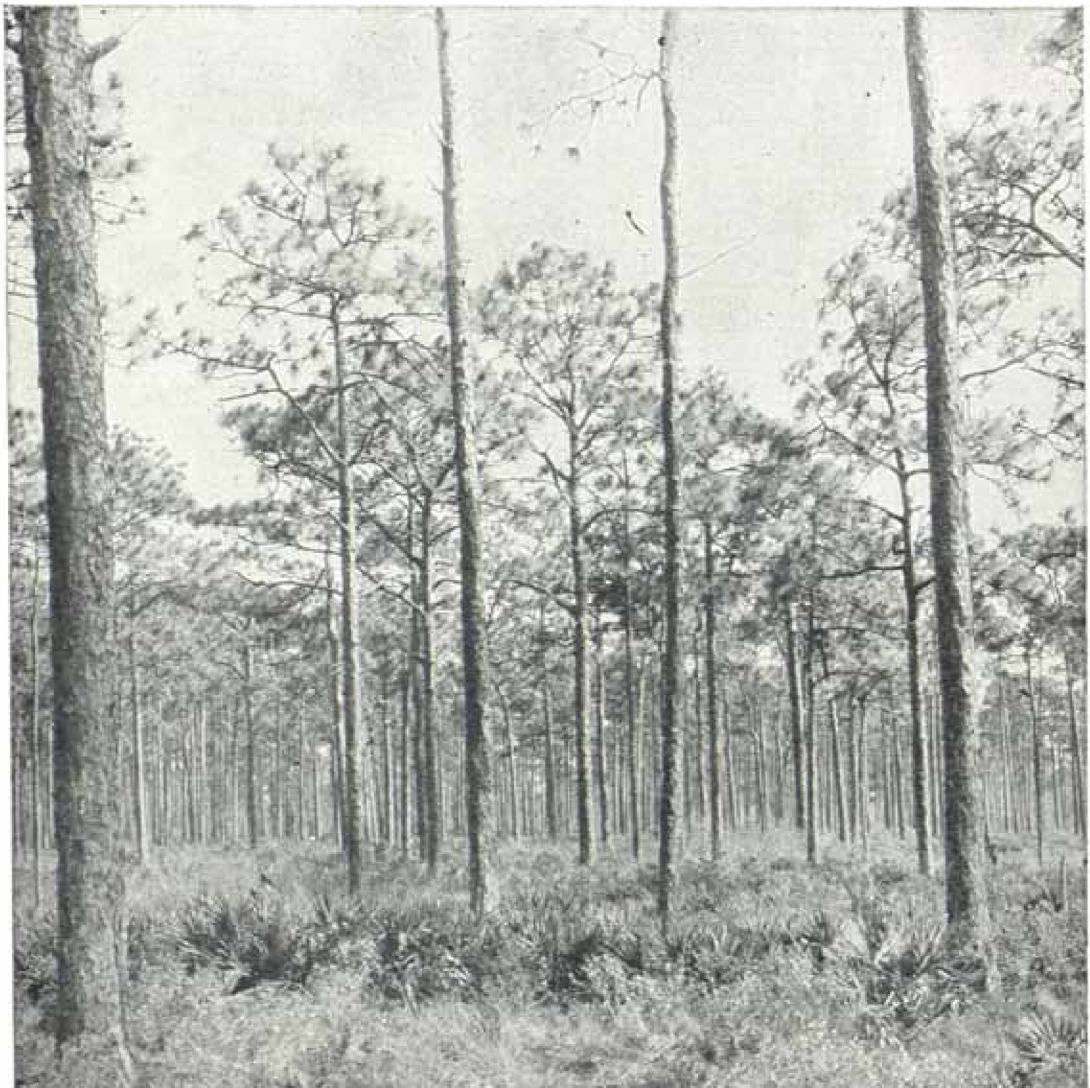

FIG. 238. Virgin longleaf pine forest, Choctawhatchee National Forest, Florida. Trees are widely spaced and much light reaches the ground, here covered by saw palmetto and grassy types of vegetation. (Courtesy of the U. S. Forest Service.)

FIG. 239. A mature stand of white pine at Cass Lake, Minnesota. In this view, there is considerable brushy undergrowth, where light reaches the ground, but in denser stands the amount of brush is much less. (Courtesy of the U. S. Forest Service.)

FIG. 240. Taiga, or the subarctic forest of Siberia. This forest, largely coniferous in type, covering nearly 4,000,000 square miles, and almost untouched as yet, constitutes one of the world's important reserves of timber, useful both as a source of pulp and for lumber. (Courtesy of Sovfoto.)

out the year. Hence swamp forests vary in character quite as much as do the forests of uplands and better drained regions.

Grasslands. Grasslands rather than forests characterize many areas in which soil conditions, poor drainage and aeration, intense cold, strong winds, deficient moisture supply, or repeated fires prevent forest growth, for grasses are well adapted to withstand all these handicaps, whereas trees in general are not. Grasses do not necessarily depend to any extent upon deeply stored moisture in the subsoil, but often, instead, upon water in the top few inches of the soil, and even this layer needs to be moist only during the warmer months. In fact, if stored water is available in the subsoil, the vegetation will normally be shrubs or trees, which crowd out the grasses.

FIG. 241. A stand of cypress along Wadboo Creek, Francis Marion National Forest, South Carolina. The projections from the roots in the foreground are cypress knees, through which it is commonly believed the trees obtain air, though this may not be correct. (Courtesy of the U. S. Forest Service.)

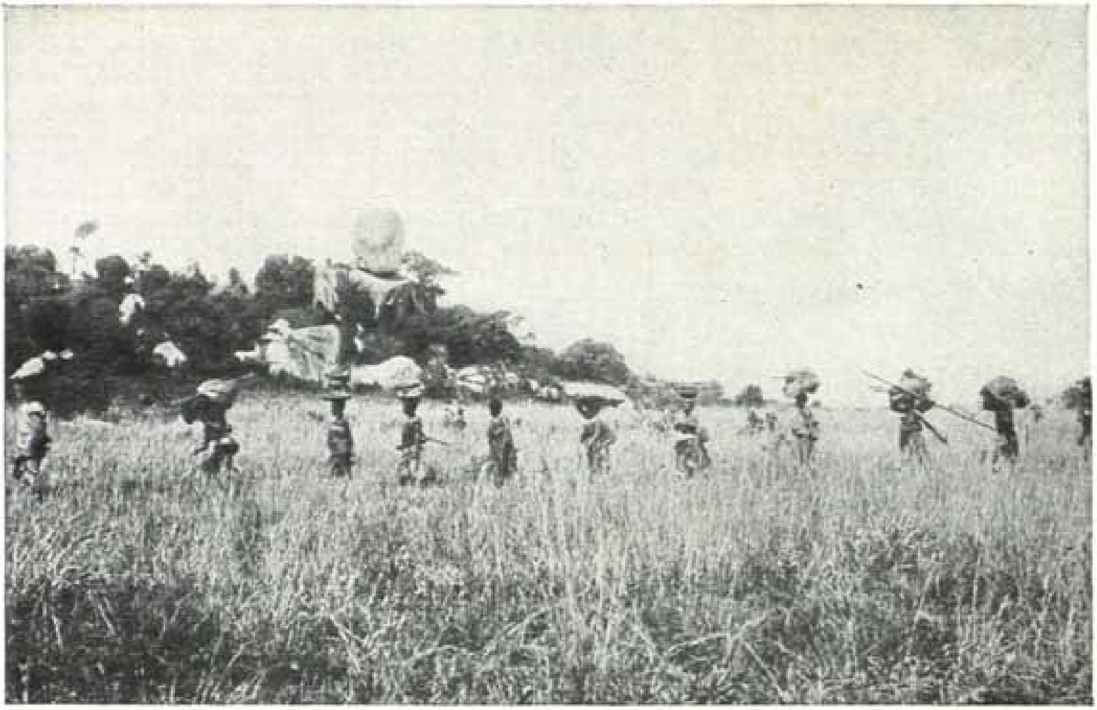

FIG. 242. Savanna grassland, southeast of Lake Victoria, Africa. (Courtesy of Theodor Benzinger.)

In grassland areas of light rainfall, there is as well a great profusion of flowering plants which affect the appearance of the vegetation cover markedly, especially in spring and fall.

Tropical Grasslands. Savanna grasslands, the vegetation of which is composed of tall, rank grasses that do not form a continuous cover or sod, occur on the drier margins of the tropical forests. In them, the grasses, which attain heights of from 5 to 12 feet or more, dry out and die down during the dry season, at which time they are commonly fired by native populations. With the coming of the rains, the grass once again springs up, at first bright and green, but later to become harsh and dry. Interspersed with the grassy vegetation are shrubs and small trees, to the low-hanging branches of which the grass often reaches. These trees increase in number and size in the zone of transition to forest to an extent that the country becomes parklike in character. On the drier margin of the savanna grasslands, tall grasses and trees are displaced by shorter grasses, likewise growing in clumps and not forming a sod, but more widely spaced than in the true savanna. These, sometimes known as "steppe grasslands," merge gradually into true desert as rainfall decreases in amount.

Grasslands of Intermediate Latitudes. The two major types of grassland of intermediate latitudes, tall and short, reflect differences in climate and accompanying soil and water relations, as affected chiefly by water supply. This relation is determined not only by the amount of precipitation, but in part by soil permeability and conditions favoring or preventing loss of water. In addition to the two major types of grassland mentioned, undrained areas are characterized by a growth of coarse, tall grasses, sedges, and reeds and, along seashores and occasionally inland, by plants which will grow in salt or alkaline water.

Tall or Prairie Grassland. Tall grasses grow where soil moisture is distributed to a depth of 2 feet or more and growth is not limited by precipitation deficiency. In such areas, rainfall ranges from 20 to 40 inches and soil moisture may extend without break to ground water; at no time is all the water stored in the surface layers of the soil brought to the surface and used by the plants.

With such an abundant supply of soil mois-

FIG. 243. Bluestem Prairie in southeastern Cass County, Nebraska, along the Missouri River, in early September. About 95 per cent of the vegetation is bluestem, but it is intermixed with a small amount of Indian grass and other plants, among which the mugwort or sage, the light-colored plant, is common. This field, with the water table 6 to 10 feet below the surface, is mowed annually, yielding 3 to 4 tons of hay per acre in good years. Contrast the height of the grasses with those in Figs. 242 and 244. (Courtesy of J. E. Weaver.)

ture, prairie grasslands depend on fires for the continuation of their existence. Repeatedly burned over, mainly by fires set by man, forest growth cannot displace the grass by encroachment; rather, indeed, grassland extends at the expense of the forest, where fires invade its margin and kill the trees. Today, with fires excluded, trees grow satisfactorily throughout the prairie which formerly characterized much of the Mississippi Valley, west to the 100th meridian, and smaller, isolated sections of the eastern United States and the Gulf Coast.

These prairies of bluestem grasses, needle grass, slender wheat grass, and other species, with bluestem most important, were one of the most distinctive features of the landscape noted by the early pioneers. In the spring and early summer, many herbaceous flowering plants almost completely covered the ground with their colorful flowers before growth of the taller grasses concealed them. Today, except in a few small areas, this cover of native vegetation has been destroyed completely, for the prairies afforded some of the most valuable agricultural land in the United States, including that of the Corn Belt.

Short or Steppe Grassland. Short grasses characterize areas where all available soil moisture is exhausted by plant growth. This type of grass-

land cover develops in areas of spring and early summer rainfall, with growth of the shallow-rooted grasses confined to a short period following the rains; then a resting stage. In a dry year, the period of growth may even be so short that maturity is not attained and seeds are not formed. The area of short grassland overlaps that of tall grassland on the drier margin of the latter, the exact boundary shifting from year to year with variation in the amount of precipitation. This boundary is not only marked by a precipitation difference but by one of soil as well, associated with the depth of penetration of soil moisture, which regulates the location of the zone of carbonate accumulation in the soil. If penetration is slight, the accumulation of carbonate will be close to the surface and short grasses will be the predominant type of vegetation; if the zone of accumulation is at considerable depth, or absent because no deposition occurs, tall grasses will be characteristic. Steppe grasses make up the grassland cover of the Great Plains, which extend westward from approximately the 100th meridian to the Rockies in the United States; to their east, the tall grasses of the true prairie are characteristic. Except under irrigation, the steppe grasslands are in general more valuable for grazing than for agriculture.

Marsh Grassland. Marsh grasslands include both fresh- and salt-water areas, as do swamps characterized by forest growth. Though salt marshes occur for the most part along seacoasts, they may also develop inland with alkalinity in interior basins or other dry or relatively dry areas, as in Oregon and California. The fresh-water marshes of the Sacramento and San Joaquin rivers of California and comparable marshes in southern Louisiana have been brought into profitable agricultural use, and the same is true to a lesser extent of those of the Everglades of Florida. Elsewhere in the United States, they are for the most part idle. Marshes with alkaline waters are valueless everywhere.

Desert and Semidesert Vegetation. Few deserts are without vegetation of some sort. Only the wastes of shifting sand where plants cannot exist

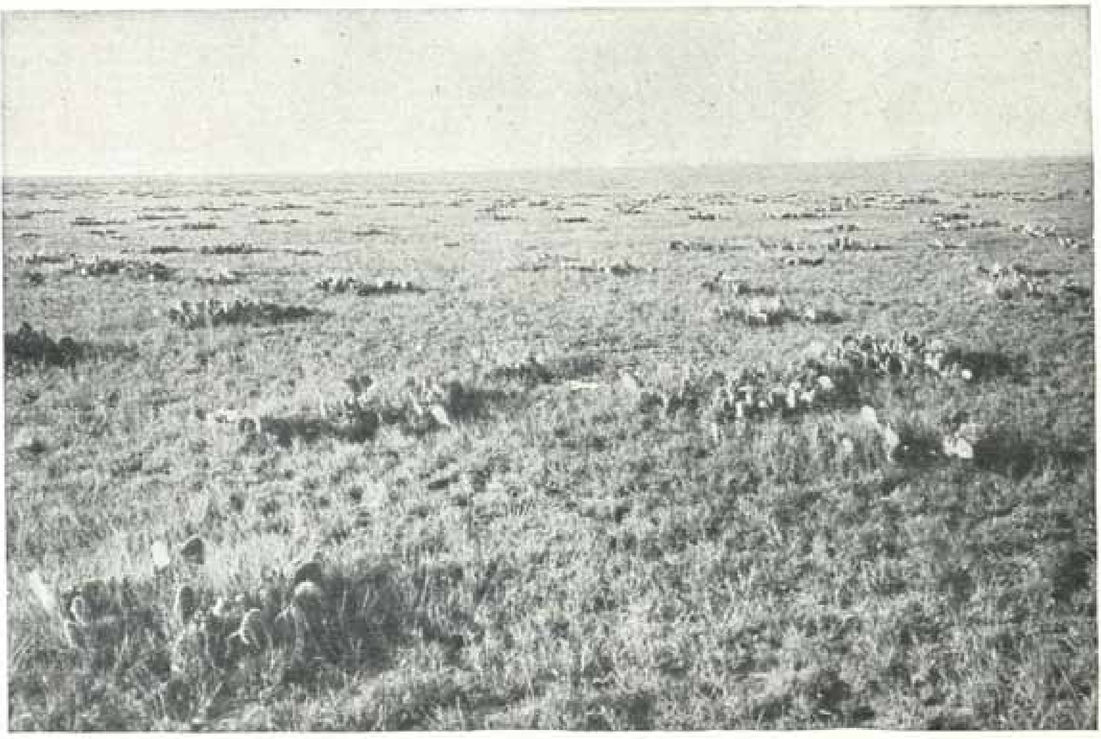

Fig. 244. Short or steppe grassland, west of Boyers, Colorado, recovering from the drought of 1934. The grasses are principally blue gramma and buffalo grass; the cacti, prickly pear, show that this is a dry area. (Courtesy of the U. S. Forest Service.)

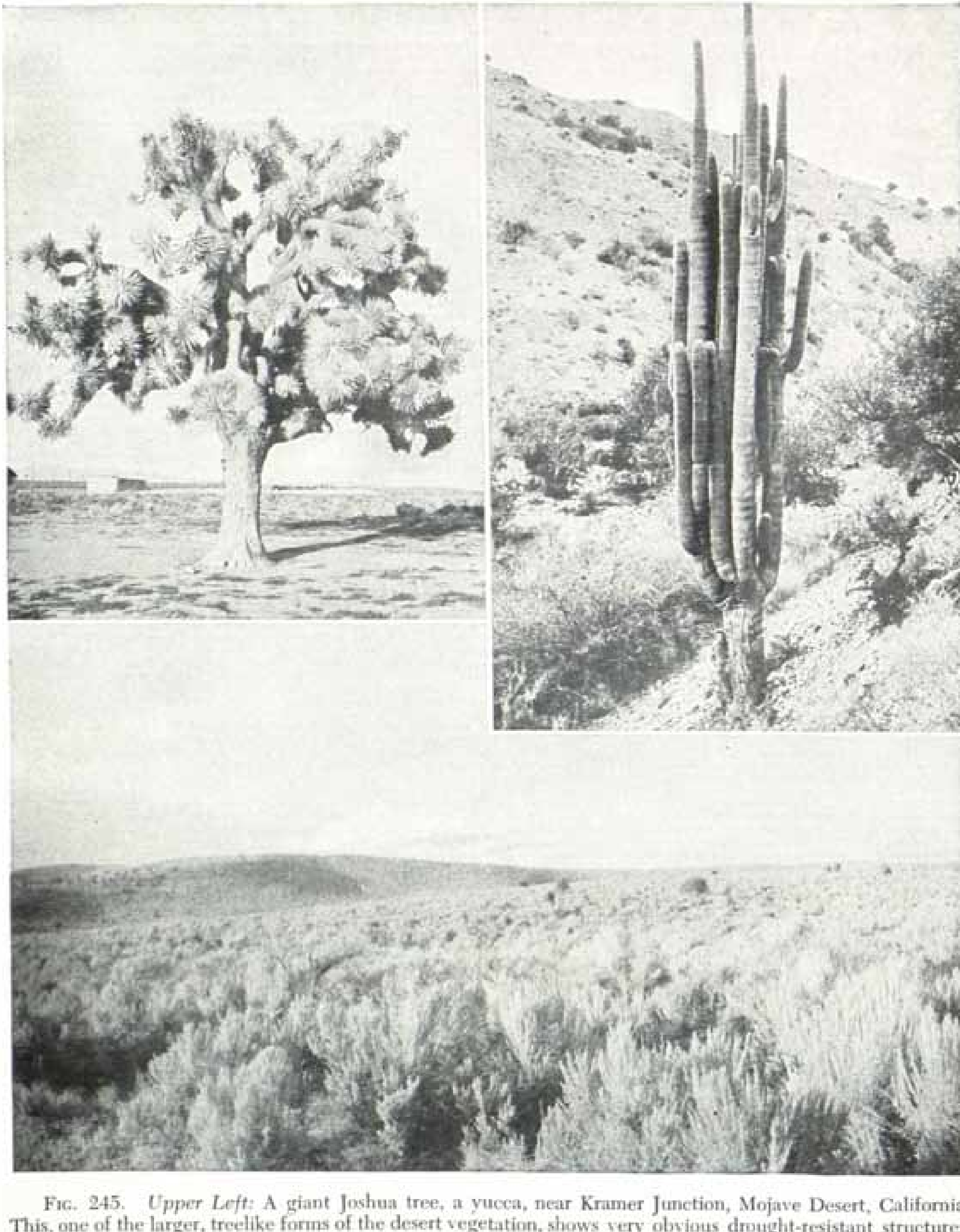

FIG. 245. *Upper Left:* A giant Joshua tree, a yucca, near Kramer Junction, Mojave Desert, California. This, one of the larger, treelike forms of the desert vegetation, shows very obvious drought-resistant structures.

Upper Right: Giant cactus, columnar in form; thorny, brushlike palo verde; and other desert plants. Colorado National Forest, Arizona.

Bottom: Sagebrush in the Fishlake National Forest, Utah. Sagebrush is a valuable desert plant, affording food for the native animals and of importance as forage for livestock. (Courtesy of the U. S. Forest Service.)

because removal of the soil from around their roots or burial by drifting sand kills them; perpetually ice-covered areas of high latitudes and altitudes; and limited tracts of bare rock are destitute of all plant life. Never, however, is the ground of deserts covered solidly with a carpet of vegetation, plants generally being rather widely spaced because of the small amount of water available. Moreover, the vegetation is peculiar in type since it must exist with a limited water supply. Therefore almost all plants have some marked structural characteristics such as reduced leaf surface; thick, leathery, waxy leaves; or an extensive root system. Many of them likewise have the ability to mature during the short period when water is available, at which time they may bloom profusely. Where soils are alkaline, often true in dry areas, additional adaptations to such unfavorable conditions are necessary. Again, in those latitudes where the winter months are cold, the perennial plants must be able to withstand low temperatures.

The vegetation of deserts is both woody and herbaceous in type, some of the forms of each attaining considerable size. In the United States, the woody, shrubby, and treelike forms include sagebrush, creosote bush, greasewood, mesquite, yucca, and others. Cacti are fleshy; other species resemble the herbaceous vegetation of better watered areas, but these live for only short periods of time after the infrequent rains. Some, such as sagebrush and palo verde, are deciduous perennials, checking evaporation when water is lacking by shedding their leaves; others, with but few and thick, leathery leaves, retain them throughout the year. The forms of the desert vegetation are often weird; even many of the flowers are of unusual colors so that desert vegetation, especially that of our southwestern deserts, is one of the advertised attractions of the area.

Tundra Vegetation. On the poleward margins of the taiga, forest growth gives way to the mosses, lichens, and sedges of the Arctic and Antarctic, and these in their turn to a continuous cover of snow and ice which excludes all plant

FIG. 246. Tundra of the Lower Ob River, Siberia, with one of the inhabitants, a Samoyed, and his reindeer. (Courtesy of Theodor Benzinger.)

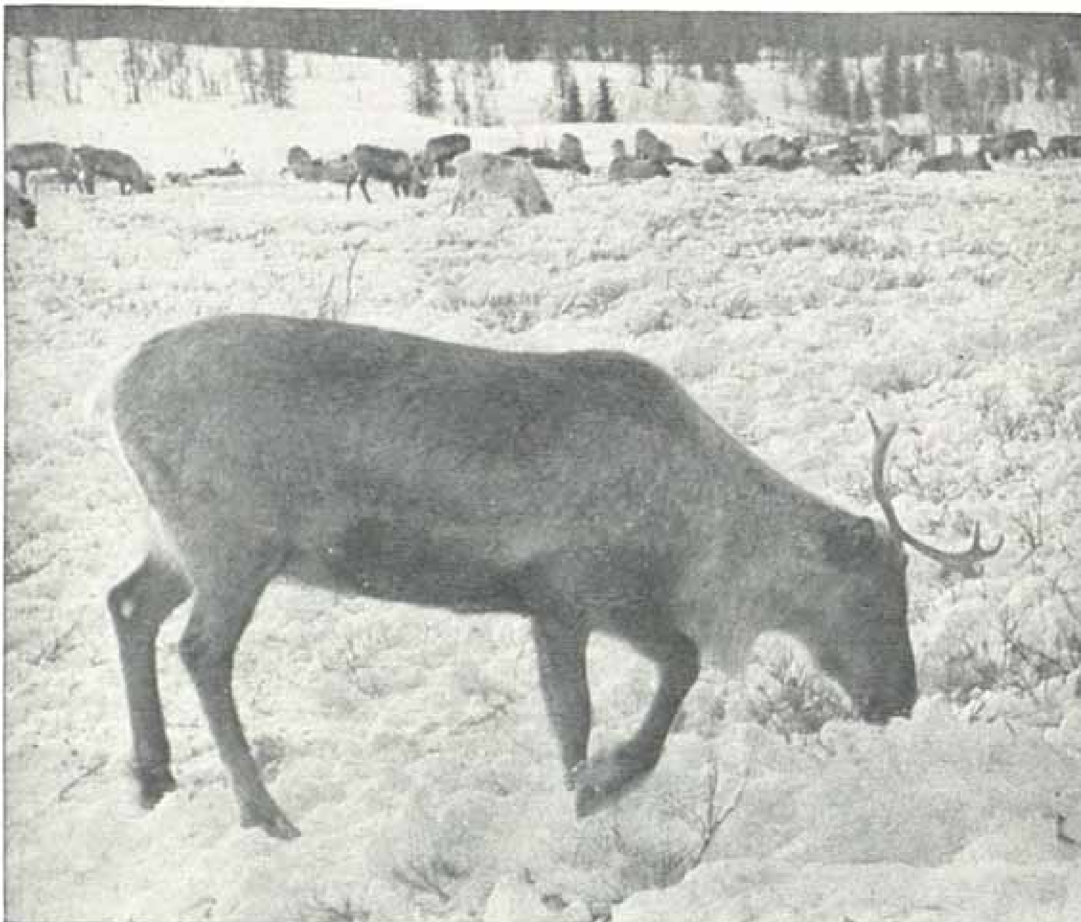

FIG. 247. This tundra region, with a few small and scattered trees on the better drained slopes in the background, is in the Nenets National District of northwestern Siberia. Its Mongoloid pastoral population is dependent largely on reindeer for support. This is made possible by the light snow cover, for winters are long and cold and precipitation is therefore light. Thus, even during the winter months, the vegetation cover is either exposed or covered to such a slight depth that reindeer can graze, as shown above. (Courtesy of Sovfoto.)

life. The portion of this area with a cover of vegetation is known as "tundra."

Nowhere in the tundra are conditions favorable for most forms of plant life. The frost-free season is everywhere short, seldom as much as two months in length. Therefore there are few annuals, and plants are mostly perennials which go through their active life cycle in a very short period of time. In addition, much of the area is flat and poorly drained. Therefore the acid, organic soils are filled with ice-cold water during the short summer, when thawing extends to a few inches below the surface. At all times the soils of this area, sometimes referred to as the "region of ever-frozen soils," are frozen below the surface to great depths. The steeper slopes with better drainage, however, may be carpeted with brilliantly blooming flowing plants during the relatively few warm months. The tundra and the desert thus have certain resemblances.

Man's Modification of the Natural Vegetation. The organic and inorganic worlds of nature are interdependent to such an extent as to ensure only gradual change in the adjustments among the different plant communities. But man is almost everywhere a disturbing element, interfer-

ing with this balance. The earth is not, it is true, best adapted to human use in its natural condition. Therefore, wherever man establishes himself permanently, or sometimes even temporarily, he proceeds to destroy certain elements of the indigenous vegetation and to substitute in their stead others better suited to his needs. These are "reluctant" growths such as cultivated crops. But with them, unfortunately, he likewise introduces species of plants, useless to himself, but so hardy as not only to interfere with production of crops but to crowd out native vegetation as well. Thus in relatively few areas occupied by man does the natural vegetation remain relatively undisturbed; in many, it has been displaced almost completely.

Though some modification is unavoidable if man is to utilize an area to maximum advantage, civilized man has unfortunately exceeded the amount of desirable change. The migratory savage hunter interferes but little with nature. He generally destroys little or no forest; he cultivates few if any crops; he seldom, if ever, extirpates useful plants. His other activities likewise commonly have but negligible effects upon the environment over limited periods of time. Even his destruction of the animals which afford a food supply is offset by his partial eradication of the carnivora which prey upon them. But, with adoption of a sedentary agricultural, or even a pastoral life, man at once declares war on the native vegetation and, with increasing progress, this war becomes ever more destructive.

Deforestation, grazing, agriculture, and other activities of advanced populations take an ever-mounting toll of plant life, many species being destroyed completely. Thus the ravages of man upset the balance of nature and she, in turn, unlooses destructive agencies previously kept in check by the organic forces he has disturbed. Human improvidence then has its inevitable reward. Accumulated ill effects are now so extensive that no longer can the immediate return remain the prime consideration if disaster is to be long deferred. That this would eventually occur has been known for many years to those who considered all the facts; today, only the most heedless can fail to comprehend the seriousness of the existing situation.

Animal Life. Except among some of the lower forms, animals differ from plants in mobility but, despite their ability to change location at will, individual species, even those which are migratory in their habits, have their range restricted by the environment. This is not to say that the fauna or animal life of two given land areas of essential uniformity of environment, but separated by barriers, will be the same, for such is not the case. The animal life of Australia, for example, is markedly different from that of the other continents, and the Americas have forms of life unknown in the Old World.

The environmental factor most directly effective in restricting the distribution of any given species of the larger land animals is plant life which, in turn, is limited by climate, soils, and drainage. The distribution of animal life is, therefore, in reality affected by the environmental complex rather than by the manifestation of one of its effects, that is, plant life. The native vegetation of an area determines the general type of the animal life because it affords food supply, either directly or indirectly. Grasslands, for example, support grazing animals; forest areas, by contrast, if the home of herbivorous animals, in general of those which browse rather than graze. In either forest or grassland, where herbivorous animals find conditions favorable, the food supply for the carnivora is abundant and they are correspondingly numerous.

Among the lower forms of animal life, distribution is so complicated that no simple, acceptable relationship to the environment appears possible of establishment, many of the lower forms apparently being able to live under rather varied conditions. On the other hand, among even the lower, though not the lowest forms, some are rather restricted in range by environmental conditions. Thus the tsetze fly, which transmits sleeping sickness, is limited to the tropics, and among other insects certain species such as woodticks are restricted to forested areas, whereas grasshoppers are characteristic of grasslands.

Fauna of Forested Areas. The fauna of forested areas varies with the character of the forest: whether hardwood or coniferous; evergreen or deciduous. In the evergreen hardwood forest of the rainy tropics, except for insects, most of the animal life within the forest is confined to the treetops, including such forms as brightly colored birds, monkeys, snakes, and climbing carnivora. On the dark forest floor, where food is limited, larger animals are few in number, though insects

are numerous here as elsewhere, but wherever the forest breaks down along stream courses, animals such as the crocodile and hippopotamus find conditions favorable.

Since the deciduous forests of intermediate latitudes are more open than those of the rainy tropics, food is generally more plentiful and larger forms of animal life are more abundant at ground level. In the coniferous forests, however, food supply is again somewhat limited and life is less diverse, except along their margins, or where the forest stand is of mixed character. In the taiga, animal life is likewise limited, but of considerable economic importance, for foxes, otter, mink, ermine, and others are fur bearers.

Fauna of the Grasslands. Grazing animals are dominant in grassland areas. Such regions in intermediate latitudes were originally the home of vast herds of bison and antelope in this continent; and, in the savannas and other grassland areas of the tropics, where man's ravages have not depleted their numbers seriously, enormous numbers of antelope, zebra, and other similar grazing animals still exist. Associated with these are the carnivora which depend upon them for food. Where trees appear in considerable numbers, with merging of forest and grassland, the animal population becomes of maximum density and diversity, under the favoring conditions for both herbivora and carnivora.

Fauna of Desert and Tundra. Sparse vegetation cover in both desert and tundra is accompanied by a correspondingly small amount of animal life on the land. In the deserts of intermediate and low latitudes, food supply is neither sufficient in quantity nor varied enough to make for either abundant or diverse forms of animal life. The tundra is further handicapped by low temperatures. Here, bird life is largely migratory; the larger grazing animals, including the caribou and the muskox, must subsist on poor and often scanty pasturage; and the larger predatory animals, typified by wolves, are relatively few in number and lead a precarious existence. Only mosquitoes and stinging flies are numerous, and these only during the short summer period. On the poleward margin of this area, land life disappears completely.

Man's Modification of Native Animal Life. Early man thought of animal life as hostile to his existence, except insofar as it afforded food supply. For a long period, in fact, his superiority over the animals was actually in question and, even yet, tigers and snakes take a yearly toll of human life in India; elephants trample and destroy native fields in parts of Africa; and wolves constitute a real danger in the far north during exceptionally severe winters. Today, however, man has won out over the larger animals in most parts of the world, though insects and other smaller forms of life still plague and harass him in many areas.

Man has, in fact, often been almost too successful in his eradication, purposeful as well as incidental, of the native animals. With destruction of the predators, some of the rodents such as the prairie dog have increased undesirably since the removal of their hereditary natural enemies. Further, introduced animals have occasionally developed into serious pests, the rabbit in Australia being a frequently cited example. Another is the brown rat in the United States, estimated by government biologists to have caused a loss of more than $200,000,000 in 1943, principally on our farms. Upsetting the balance of nature by destruction of the forest cover which sheltered and afforded food for the native animals; drainage of wet land and destruction of the breeding places of many birds; man-set fires which have devastated both swamp and upland forest and wiped out wild life; and pollution of the streams which has killed the fish; plus deliberate and planned programs of extinction, have all contributed to a present condition to man's disadvantage.

Man and Plants and Animals. Though some aspects of the original environment of every area, including certain elements of the fauna and flora, handicapped early man, the life forms as a group were an asset. They supplied food; material for shelters, clothing and utensils; and, later, beasts of burden, to decrease drudgery and increase production. Dependent at first upon such wild plants as afforded seeds, roots, tubers, or other structures suitable for human food, man early succeeded in improving their quality and yield by cultivation, thus assuring himself of a more adequate and better food supply. Moreover, he lightened his labors by domestication of the more promising of the wild animals such as horses and cattle, using them as draft animals. This was a long step forward. He also made use of birds and animals for his company and amuse-

ment but, in general, animals were domesticated primarily for utilitarian purposes and principally for use as beasts of burden.

The continents were unequally supplied with kinds of plants and animals suitable for human food and with species which could be domesticated to advantage. Certain of the smaller grass-like plants, which today furnish a large share of our cereal food supply, were widespread, but some like maize, or Indian corn, were unknown in Europe until after discovery of the Americas. Before then, also, the potato, though today a very important crop, was unknown in northwestern Europe. In addition to the two preceding crops, the Americas also contributed tobacco and the tomato to world agriculture. Though fortunate in its native vegetation, the Americas were not so generously endowed with native animals which lent themselves to effective use. In North America, at the time of its discovery by Europeans, but one animal, the dog, had been domesticated by the native populations. In South America, an additional animal, the llama, had been pressed into service. Both of these are small and of only slight value for use in transportation; neither lends itself to effective use in agriculture. The native populations of the Americas were thus unable to make more rapid advances in civilization, in part through lack of satisfactory beasts of burden.

Though man's war on the larger animals has been won on most fronts, that on the insects is still in progress. In many areas, in fact, they are holding their own and in a few cases causing man to evacuate. Thus the common housefly, a carrier of typhoid and other diseases, wins many a battle against the yellow races of eastern Asia. Similarly, the mosquito is a formidable enemy as yet in the great swamps of both high and low latitudes, and in the coniferous forests as well as those of the rainy tropics. Worse, certain species are carriers of malaria and yellow fever, diseases which incapacitate or carry off thousands each year.

The war on the lower forms of animal life is also still in progress in well-watered areas where man has established himself satisfactorily. In such areas, the known number of fruit pests alone numbers nearly 300 varieties. Each year, gardens are attacked and often ruined by cutworms, beetles, grubs, and other enemies; moths and borers destroy our trees; army worms, corn borers, and others, our crops; in the South, cotton succumbs to the boll weevil. Ants are often a veritable scourge in the humid tropics and locusts are a similar affliction in the drier grasslands.

Profitable grazing of livestock is difficult, or even impossible, in many areas in the tropics, because of insect pests. Where it is practiced, despite this handicap, returns are generally low, for both the meat produced, and the hides as well, are of poor quality. Generally, therefore, where the grazing industry exists in such regions, it serves only as the basis for support of native populations, not to supply products which enter world trade.

Government entomologists estimate the annual national loss caused by insects at $1,600,000,000. Though mosquitoes lead in causing this, the ravages of the boll weevil yearly cost the country $121,000,000, and those of the corn borer and housefly only slightly less. Even the common clothes moth exacts an annual toll of $22,000,000, and termites nearly double that amount. Further, with removal of the barrier of isolation, and particularly since the development of air transportation, these enemies widen the front and the extent of their attack, causing increasing damage and necessitating the expenditure of huge sums for the establishment of quarantines to check their spread, and for their eradication where they have become established.

Already many foreign pests, including the gypsy and brown-tail moths, the European corn borer, the Japanese beetle, the boll weevil, and others have gained entrance by rail, ship, and airplane, and some 20,000 or more other species, not yet known in the United States, wait at our borders. Even with quarantines established, spread of these pests is difficult to control. Thus despite all our efforts, including the enlistment of apparently useful insects or other forms of life as aids, the gypsy moth now occupies an area of 35,820 square miles or more in New England and adjacent states; the corn borer has advanced to the west into Minnesota; and the boll weevil has invaded all the cotton-growing areas in the United States except those of California, Arizona, New Mexico, and western Texas. Many other pests have spread with equal or even greater rapidity. Not in our generation, and probably never, will it be possible for man to much more than hold his own against his insect and other small enemies.

QUESTIONS AND EXERCISES

1. Why is continuous though slow change in the character of the native vegetation of an area the rule? How does this explain relict plant communities?
2. How does the character of the native vegetation afford an indication of the general environmental characteristics of an area?
3. How do plants provide against climatic conditions unfavorable for growth? How does shedding of leaves accomplish this?
4. What is a "plant community"? Name some of the more important of these communities and discuss their composition.
5. Under what conditions do forest communities develop? Grassland communities? State the various types of grassland and describe the characteristics of each.
6. What are the principal subtypes of forest communities and the characteristics of each?
7. Describe the characteristics of desert vegetation.
8. Describe the vegetation of the tundra. To what climatic conditions is this vegetation adapted? In what respects do the vegetation of the dry desert and tundra resemble one another?
9. How do man's activities affect the character of the native vegetation? In what respects have these activities been beneficial and in what respects detrimental?
10. What crops did the Americas contribute to European agriculture? Of what importance was this contribution?
11. Why is distribution of animal life less simple than that of plant life? Upon what factors does distribution of animal life depend?
12. Compare the fauna of forested, grassland, and tundra areas; that of the different types of forest.
13. How have human activities affected native animal life? How has native animal life affected man?
14. Discuss man's war on the insects.

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This book, as indicated by its title, treats of the geography of animal life.

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This publication, to which several references have been made in previous chapters, covers in considerable detail man's misuse of the various assets of the natural environment, in his attempts to utilize them as a basis for support. The chapter cited above discusses the desirability of conserving wild life, both plant and animal, in a clear and comprehensive manner.

Chapter Twenty-Seven

SPACE RELATIONSHIPS

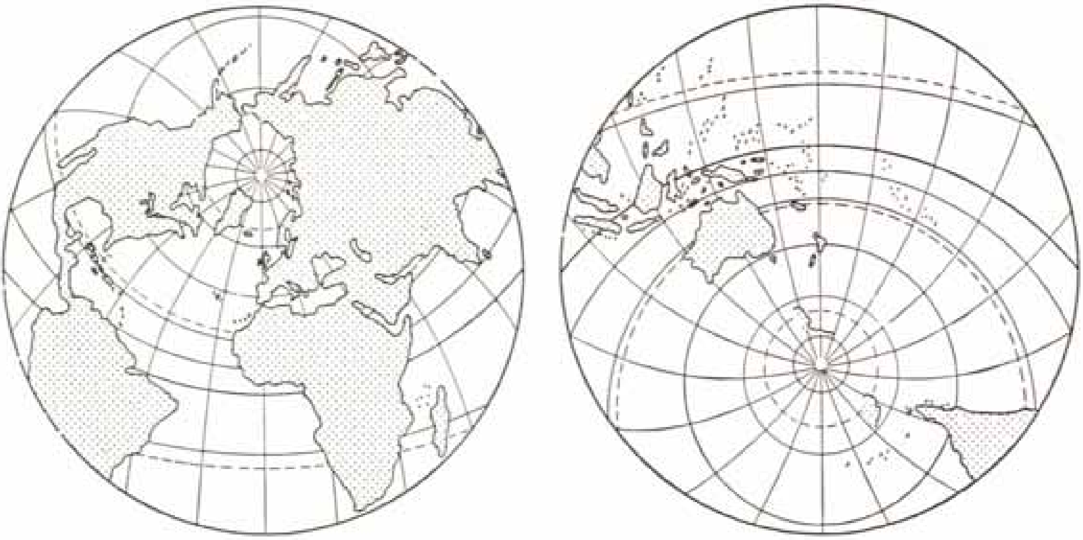
Space Relationships and Individual Choice. When the city dweller chooses his residence, he takes into consideration the appearance and state of repair of the house; the number, size, and arrangement of its rooms; and the heating, plumbing, and other conveniences. Similarly, the farmer investigates land productivity and the adequacy of the farm buildings before locating. In neither case, however, is this information alone sufficient as a basis for intelligent decision. Thus the city resident should also know the accessibility of the site under consideration to transportation, stores, schools, and churches; the size of the satisfactory neighborhood; and whether it is confined to a single street or compact and protected from close-by undesirable surroundings. The farmer should likewise know whether the tract of good land in which the farm is located is large or small; whether the shape of this body of land is such that adequate community services can be maintained economically; and he should also have information concerning the nearness and accessibility of markets, that is, whether good roads and rail service are available.

Thus it is necessary, in either city or country, to know both the immediate or internal conditions of the site under consideration and its space relationships: the location, size, and shape of the area in which the house or farm is located, for though either a house or a farm may appear desirable after detailed examination of the premises only, additional investigation of its spatial relationships may disclose the reverse to be true. This is likewise a fact for units larger than houses and farms. For example, an area of considerable size may be favored by climate, productive soils, and topography, yet be so inaccessible that its agricultural value is slight. Again, the size of an otherwise good agricultural area, if too small, will decrease its desirability and, similarly, its shape many constitute a handicap. For these reasons, space relationships, though considered last among the environmental factors, are of great importance, since they enhance, decrease or, in extreme cases, offset completely other favoring environmental assets.

Location. Mathematical location, stated in degrees of latitude and longitude, or in other units with definite quantitative values, is useful in that it enables definition of a point or the boundaries of an area with reference to the entire surface of the spheroidal earth, but such location is not necessarily important in limiting the degree of opportunity or the character of human occupation. For example, that a certain point on the earth's surface 2 miles from Lebanon, Smith County, Kansas, 39° 50′ North latitude and 98° 35′ West longitude, has a mathematically or "geographically" central location with reference to the United States fixes its position, and is possibly an interesting fact, but otherwise of little significance for, as such, it neither affords nor refuses opportunity, even though the spot is marked by a monument.

By contrast, relative location, or location of an occupied area with reference to others, both occupied and unoccupied, as measured in terms of *accessibility*, not miles, is of great importance. If easily accessible, the location of an area is said to be "central"; if accessible only with difficulty, to be "peripheral" or marginal. A central location thus ensures ease of access to markets for both sales and purchases, whereas a peripheral location imposes the handicap of lack of such an advantage.

Locational Advantages of the Hemispheres. The earth may be divided into an infinite number of hemispheres, the boundary line between



LAND HEMISPHERE WATER HEMISPHERE

FIG. 248. The Land Hemisphere, though including approximately six-sevenths of the land, is still more than half water; the Water Hemisphere, with only one-seventh of the earth's land surface, is approximately fourteen-fifteenths water. This large percentage of water in both hemispheres reemphasizes the great extent of the ocean as compared with that of the land.

the members of each pair being known as a "great circle," so called because it is of maximum diameter and circumference. With the equator as the dividing line, the resulting hemispheres are the Northern and Southern, with a location in the former much better than one in the latter. This is because most of the land masses of the world, and the most highly developed and therefore most important areas, lie north rather than south of the equator. Similarly, the earth may be divided into the Eastern and Western hemispheres and these likewise differ in desirability with respect to relative location. The maximum of difference in locational values among the pairs of hemispheres commonly recognized and named is that existing between the Land and Water hemispheres, divided by the great circle which passes midway between the pole of the Land Hemisphere, near London, and its antipode, the pole of the Water Hemisphere, located in New Zealand.

Locational Advantages of the Continents. Of all the continents, Europe is most favored by relative location at present, for it is in the Northern Hemisphere, where most of the industry and commerce of the world are concentrated today. It likewise fronts on the North Atlantic Ocean, where the most important of the great trade routes of the world are located and, to emphasize advantage still farther, it is near the pole of the Land Hemisphere. By contrast, Australia, with a location sometimes referred to as "down under" because of its antipodal location with reference to Europe (see Fig. 426), is handicapped greatly by its relative location, the poorest of all the continents. North America, though slightly less favored with respect to relative location than Europe, ranks second among the continents, with a strong probability that the future will improve this standing. Like Europe, in both the Northern and Land hemispheres, North America fronts on both the North Atlantic and the North Pacific, the latter increasing steadily in importance as a carrier of trade with the development of eastern Asia. It is interesting to note that there is a considerable though not complete correspondence between the degree of development of the individual continents and the excellence of their location. Thus Europe, the most highly developed, has the best location; North America, with the second best location, is likewise second in degree of development. Where this correspondence disappears, for example in Australia, other favoring factors more than offset the handicaps

imposed by the poor relative location of that (particular) continent.

Locational Advantages of Islands. Islands immediately off continental shores, commonly representing exposed portions of the continental shelf, enjoy approximately the same locational advantages as do the continents with which they are associated in place and in general, therefore, they do not suffer from repressive isolation. With oceanic islands, however, this is not true, for some of them reach the extremes of peripheral location and associated inaccessibility for the known inhabited world. Because of this fact, such islands have often served as prisons or places of banishment, as did St. Helena for Napoleon.

Oceanic islands generally represent the results of local crustal deformation and accompanying igneous activity, the island masses frequently being of volcanic origin in major part and bare of life when they first appear above the ocean surface. Far from other land, few forms of life can reach them. Seeds borne by the wind or by birds, and some which will float and survive soaking in salt water, supply the plant life, which is therefore limited in number of species. Animal life is equally limited as to kinds. Few or none of the larger forms are found, birds, insects, and other flying forms being best represented. Occasionally, this isolation may in time even lead to the development of new varieties, or permit the preservation of life forms found nowhere else, as on the Galapagos Islands, where uncouth sea lizards and giant turtles, the latter of which gave the name to the island group, have attracted attention since the days of the sixteenth-century Spanish navigators.

Because off the beaten track, oceanic islands like Pitcairn, populated by descendants of the mutineers of the English ship *Bounty*, have sometimes attracted those desiring to escape the attention of the world but later their descendants are handicapped in satisfying many wants, for ships do not call frequently. Thus even such a simple item as sewing needles may be impossible to secure except after a lapse of months. Even today, when we live in "one world," and though ignorance of current world events may be remedied by radio, lack of the world's goods in quantity and kind desired at a given time still persists. Certain of these peculiarities resulting from extreme isolation give an island such as Pitcairn a news value entirely out of proportion to its areal or economic importance, causing stories concerning it to appear irregularly but with relative frequency in the news columns of our papers.

Locational Advantages of Countries. Individual countries, as well as continents and islands, either profit from central location or suffer from inaccessibility imposed by peripheral location. A country such as Chile, for example, located far off most of the major trade routes, suffers in its commercial relations as a result of this locational handicap, whereas the United States, fronting on both the great northern oceans which "connect" the most highly developed portions of the earth's land surface, is favored by locational opportunity. Relative location has undoubtedly played an important part in shaping the destiny of Great Britain as a world power, though other factors, probably at least equally effective, have likewise been important. Situated at the pole of the Land Hemisphere, the opportunity presented by such a location is obvious and it is therefore in no way remarkable that the acquisition of far-flung dominions and other landholdings has accompanied the commercial expansion facilitated by location. All countries, in either greater or lesser degree, show these same effects of accessibility or its lack, though as has been pointed out earlier the effects may be obscured in some degree by those of other environmental factors.

Cities and Their Locations. Inasmuch as every urban aggregation represents a focus for some area, large or small, it is inevitable that each such aggregation possesses a central location with reference to the area which it serves. This focal asset derives from the pattern of the transportation mesh and any relationship it may appear to bear to mathematical location is ordinarily more or less fortuitous. That a mathematically central location will not in itself ensure important urban development has been demonstrated many times, deliberate selection of such a site, under the erroneous belief that important growth would follow, not securing the expected results, whereas at an off-central mathematical location, at a focus of important roads and rail lines some distance away, a center of some size developed. In some cases, in fact, the central location which makes the city a possibility is far from a mathematically central location with reference to the area served. New York City, for example, which serves as an outlet for much of the trade of the Upper Missis-

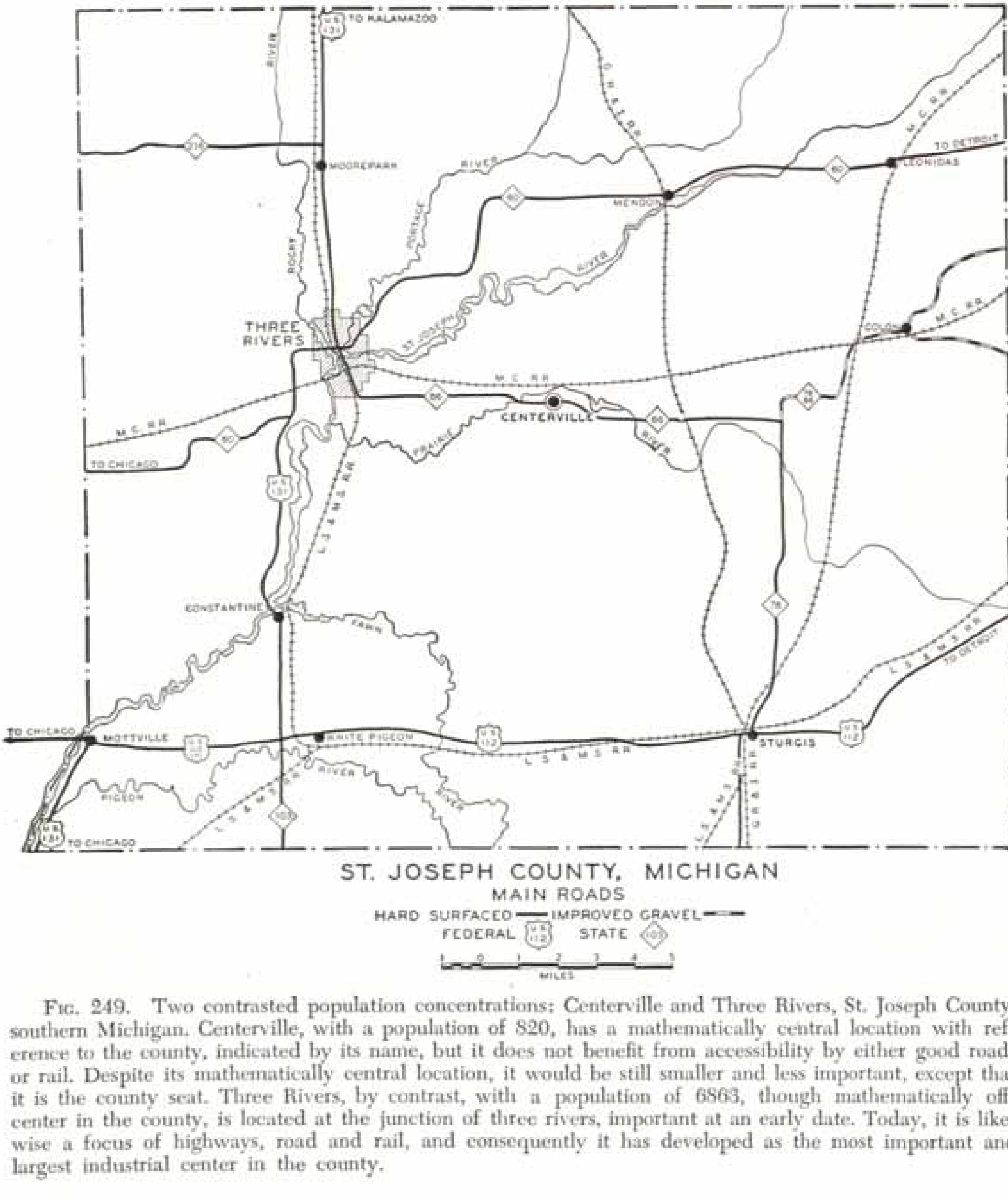


FIG. 249. Two contrasted population concentrations: Centerville and Three Rivers, St. Joseph County, southern Michigan. Centerville, with a population of 820, has a mathematically central location with reference to the county, indicated by its name, but it does not benefit from accessibility by either good roads or rail. Despite its mathematically central location, it would be still smaller and less important, except that it is the county seat. Three Rivers, by contrast, with a population of 6863, though mathematically off-center in the county, is located at the junction of three rivers, important at an early date. Today, it is likewise a focus of highways, road and rail, and consequently it has developed as the most important and largest industrial center in the county.

sippi Valley, has a marginal mathematical location with reference to this area for which it is a major outlet, though its relative location with reference to this same area is central, because it is at a focus of existing means of communication and transportation and therefore accessible from all parts of the hinterland served by the city.

Since accessibility is dependent on means of transportation, great metropolitan centers as we know them today are a recent development because, prior to the construction of good roads, railroads, and other means for the effective movement of goods, it was impossible to focus the trade of a large area upon any single center. Thus in 1790, at the time of the first Federal Census, when roads were poor and rail lines were un-

Fig. 250. The lower end of Manhattan Island, New York City, today probably the greatest urban aggregation in the world, made possible by development of air, water, and land transportation to the point where it is possible to focus the trade of a large area on a single center. (Courtesy of Underwood and Underwood.)

known, there were only five towns with populations in excess of 5000 persons in this country and the largest of them all, New York, confined to Manhattan Island at that date, had a population of only 33,131. Not until after the opening of the West by the Erie Canal did this condition change materially. Similarly, less than 30 years ago, there was only one city with more than 1,000,000 inhabitants on all the Asiatic continent with its enormous population, though today

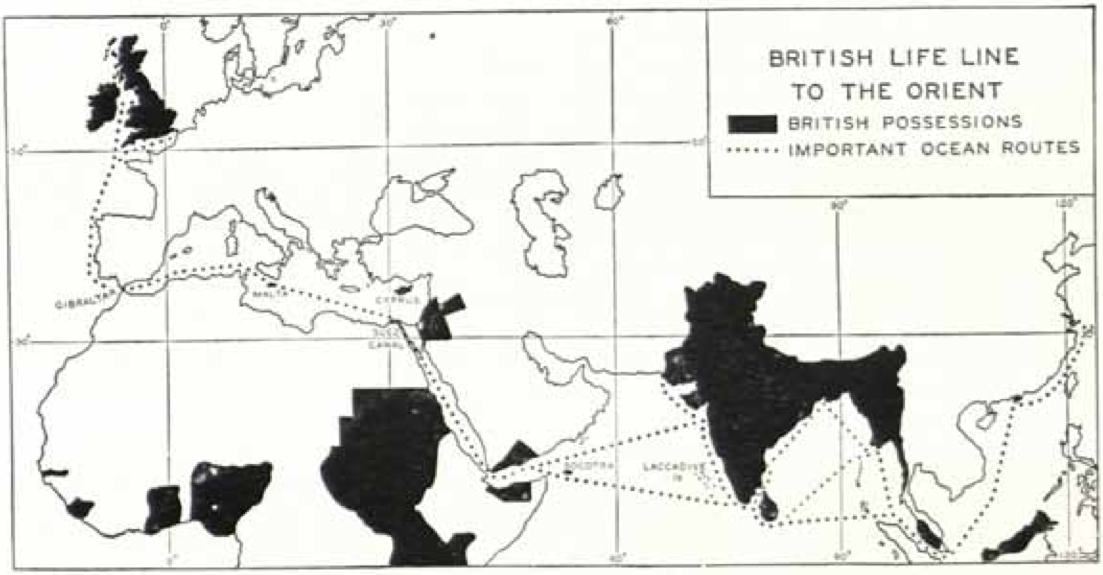


Fig. 251. A British "life line," the route to the Far East and Australasia. Note the several islands and other holdings, some recently granted independence, which protect this route.

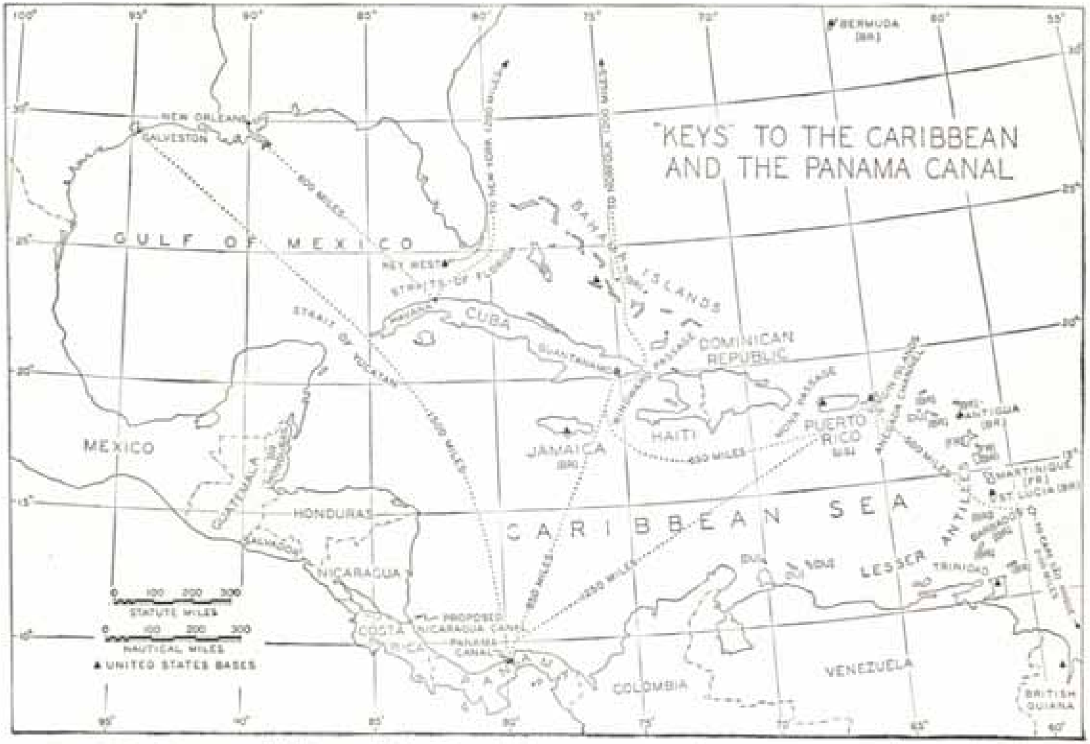


FIG. 252. Strategic holdings of the United States protecting the eastern approaches to the Panama Canal. With two coasts to protect in time of war, these bases are of vital importance.

there are several, all having attained their present size only after improvement of transportation facilities. It should not be inferred from this, however, that movement of freight is effective everywhere in Asia, since in most parts of China, for example, the farmer cannot, even today, market his grain except within a radius of a few miles from the producing area. The changes in degree of urbanization, as affected by improvement of transportation, will be considered more fully in a later chapter in connection with a more detailed discussion of cities and their development.

Change in Value of a Given Location. The value of a given location, no less than that of other factors of the environment, is subject to change with time. This change in value may result from: (1) increase or decrease in development of the tributary area; or (2) changes in means of transportation which alter the relative importance of various focal points. These may operate singly or in combination.

Thus a newly occupied area of great natural assets may produce an increasing volume of trade which is concentrated on a given point or urban center, thereby leading to a rapid increase of its importance and size; or the reverse may occur with exhaustion of the original resources and a decrease in the volume of trade. Either of these may take place without any modification of the transportation mesh, though in general this is not what occurs.

Change in the means of transportation is likewise important in producing alteration in both the actual and comparative advantages of given locations. In the earlier history of the United States, for example, the rivers of the Mississippi Valley were perhaps actually, and certainly relatively,

POPULATIONS OF ST. LOUIS AND CHICAGO FOR SELECTED DECADES

	1840	*1850*	*1860*	*1870*	*1880*	*1930*	*1940*
St. Louis	16,469	77,860	160,773	310,864	350,518	821,960	813,748
Chicago	4,470	29,963	109,260	298,977	503,185	3,376,438	3,384,556

more important as highways than they are today, for roads were poor and there were no rail lines, under which conditions a focal location with reference to river highways was very important. St. Louis, with such a location, as inspection of a map will show, was therefore for many years the largest and most important city of the interior, west of the Appalachians. As will be seen from the table on page 354, it was nearly four times the size of Chicago in 1840, yet by 1940 Chicago was more than four times the size of St. Louis. It will be noted that, even as late as 1870, the two cities were of approximately the same size and that, not until after 1870, with improvement of rail transportation and accompanying decline in the use of rivers, did the present discrepancy in size of the two assume continually increasing importance, as the shift from river to rail gave Chicago a superior relative location.

Strategic Location. Certain areas, quite apart from whether centrally or peripherally located, possess strategic significance in times of peace, and especially in times of war. In times of peace, they influence the flow of trade; in times of war, they serve as bases for the protection of national economic interest. Areas with such strategic locations include straits, isthmuses, mouths of navigable rivers, mountain passes, islands located on major ocean routes, and points controlling or protecting canals, all located on or near highways of trade. All nations strive to acquire such strategic points as are necessary to protect the interests of the country concerned and, the more important the commercial interests of a given country, the more extensive these holdings, often of strategic importance only. This is illustrated by the numerous and widely scattered bases of this type acquired by Great Britain to protect her sea routes, holdings so widespread and numerous it is said correctly that "the sun never sets on the British flag." One of these routes, by way of the Mediterranean, the Suez Canal, the Red Sea, and the Indian Ocean to the British Dominions of southern and southeastern Asia, and the southwest Pacific is of such great importance that it has been protected by the acquisition and fortification of several islands and other points, stretching from Gibraltar to Singapore and beyond. Control of this route is of such great importance that the foreign policy of Great Britain is shaped to prevent any territorial acquisitions or national alignments threatening this line of communication, which explains many actions of the British and their interest in the activities of the powers bordering the Mediterranean.

The United States likewise has a sea route, that from the Atlantic to the Pacific by way of the Panama Canal, which is of great importance, both economically and strategically, since it obviates the necessity for a long and hazardous trip around South America. The most vulnerable portion of this route is the Panama Canal, which connects the Pacific Ocean with the Caribbean Sea. Fortunately, the islands which border the Caribbean constitute a chain blocking approach to the Canal from the east, except by a few passages, most of which have been protected adequately for some time by several near-by bases. Of these older bases, that of Guantanamo is leased; the others are owned. Until late in 1940, defense was weak to the southeast, in the Lesser Antilles, but this has now been remedied by lease from Great Britain of bases in Guiana, Trinidad, St. Lucia, and Antigua. The first one of these four will afford an air base only; the other three, both air and naval bases, if desired. Secondary protection to the passage between Cuba and Haiti has alsc been assured by a new air base in Jamaica. To the north, additional protection has been secured by an air base in the Bahamas and, still farther to the east, by an advanced base for both fleet and aircraft in the Bermudas. These last three bases, like the preceding four, were secured by lease from Great Britain. Thus our present holdings convert the Caribbean into an American lake and afford adequate protection to the Canal on the east, as well as bases from which our fleet and air force can operate to guard our eastern seaboard and much of eastern South America. On the Pacific side, a base on Indefatigable Island, one of the Galapagos group of 12 large and several hundred small islands with many volcanoes, some active, serves to protect the western approaches to the Canal.

Since the late war has indicated the desirability of additional strategic outposts in the western Pacific as a protection against would-be aggressors, we shall retain bases in that area. These will form an approximate triangle, with one apex a few miles south of Kyushu, in Japan; a second in the Carolines; and a third in the Philippines. These should afford adequate protection to our Pacific coast.

Form. The shape or form of an area, as well

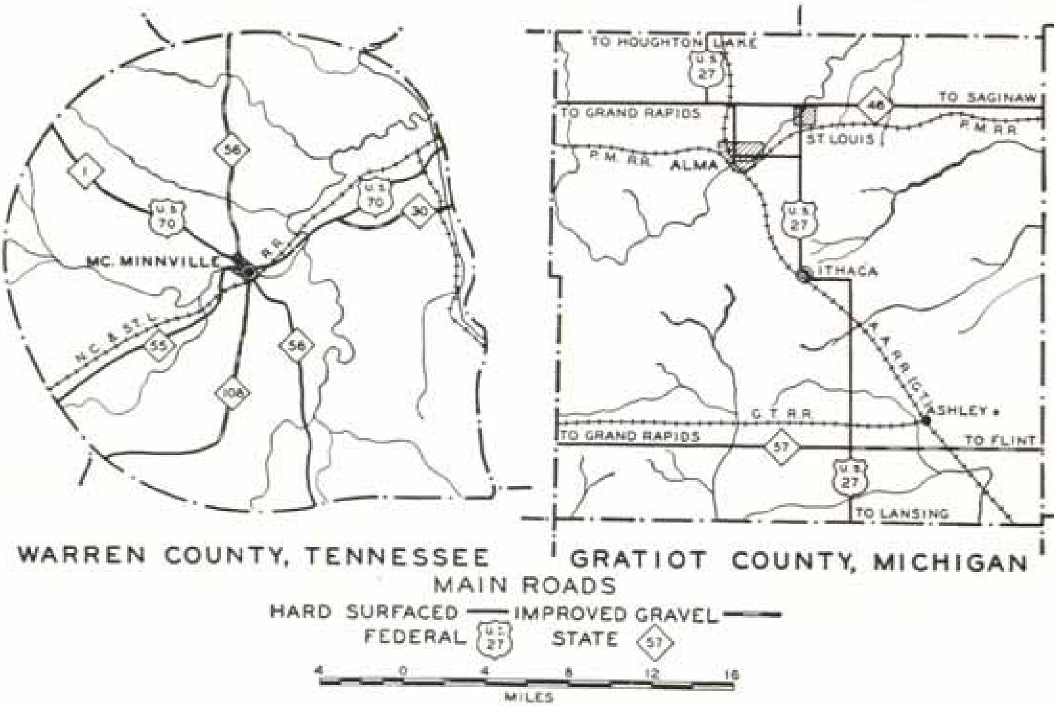


FIG. 253. Warren County, central Tennessee, an example of a compact, circular county. Such a shape, however, necessitates irregular boundaries and often considerable attenuation in bordering counties. By contrast, the rectangular, compact subdivisions of southern Michigan, of which Gratiot County is typical, assure approximately equal advantages of shape to all counties.

as its relative location, has much to do with determining its desirability. On the one hand, an area may be compact, with the maximum of areal concentration within a given perimeter attained where the form is circular; on the other, it may be attenuated, or long and narrow, which ensures maximum extent of boundary as contrasted with that associated with the circular shape. Insofar as form alone is concerned, the more compact an area, the more favorable for man are conditions within its boundaries.

Compact and Attenuated Counties. The advantages of compactness in small political subdivisions have long been recognized, this recognition finding expression in the original delimitation of several roughly circular, early counties in central Tennessee and the Bluegrass region of Kentucky. Warren County, Tennessee, furnishes an excellent example of this type of county. This shape provided for maximum ease of communication within the county, for the radiating roads focused on the county seat, the economic as well as the governmental and mathematical center of the small political unit. For the complete subdivision of larger units such as states, it is of course true that the most practical compact county is the common rectangular one of those parts of the United States surveyed into townships and sections, rather than the circular or roughly circular counties organized in some of the early settled areas of the South.

Compact and Attenuated States. Attenuation of a state, illustrated by California, and possibly even better by Tennessee, is likewise undesirable. In California, the results of attenuation, associated with a north-south extent of slightly more than 700 miles as contrasted with a width of less than one-third that distance, and much less than that in the inhabited area, has been the inclusion of such diverse areas within the state boundaries that the northern and southern portions differ greatly in economic interests and political views. This diversity is reflected in almost every election, and possibly may be said to

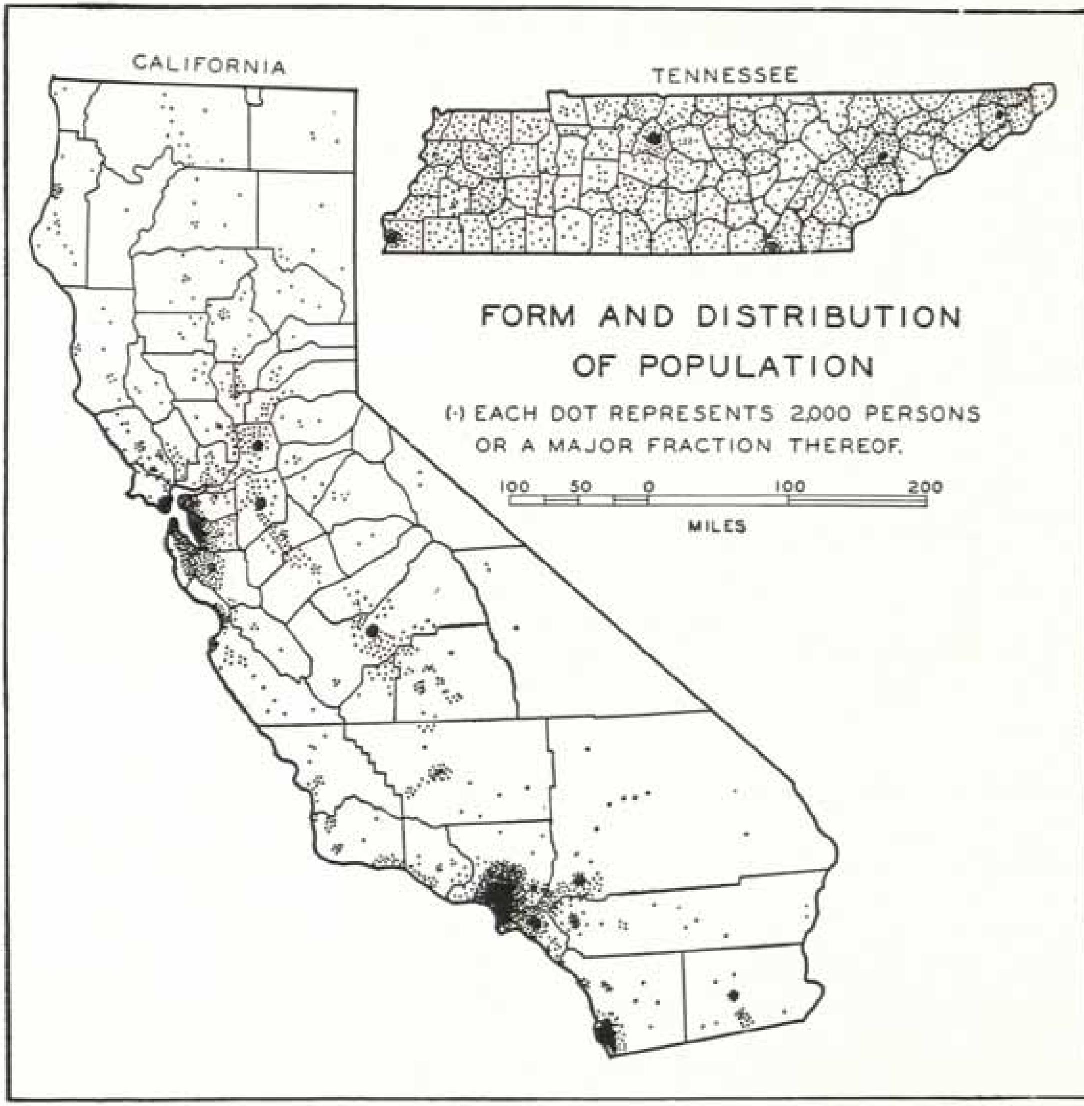


FIG. 254. Two attenuated states: California and Tennessee, with attenuation of the ecumene, or inhabited portion, particularly marked in California.

find visible expression in two state universities, perhaps as well resulting from distances of travel made necessary by attenuation.

The attenuation of Tennessee is even more pronounced in certain respects. Nearly 500 miles in length from east to west, it is only about 120 miles in width from north to south in its widest part. Therefore its boundaries, though not its population distribution, show greater attenuation than do those of California. Though the smaller latitudinal or north-south extent of Tennessee does not involve the considerable variation in climate which characterizes California, the changes in the character of the underlying rocks from east to west, together with accompanying changes in topography and soils, have made for at least as great if not greater changes in economic interest and population composition, all conditions which interfere with evolving any program equally satisfactory to all parts of the state. In the period prior to the Civil War, some parts of Tennessee found Negro slave labor profitable and

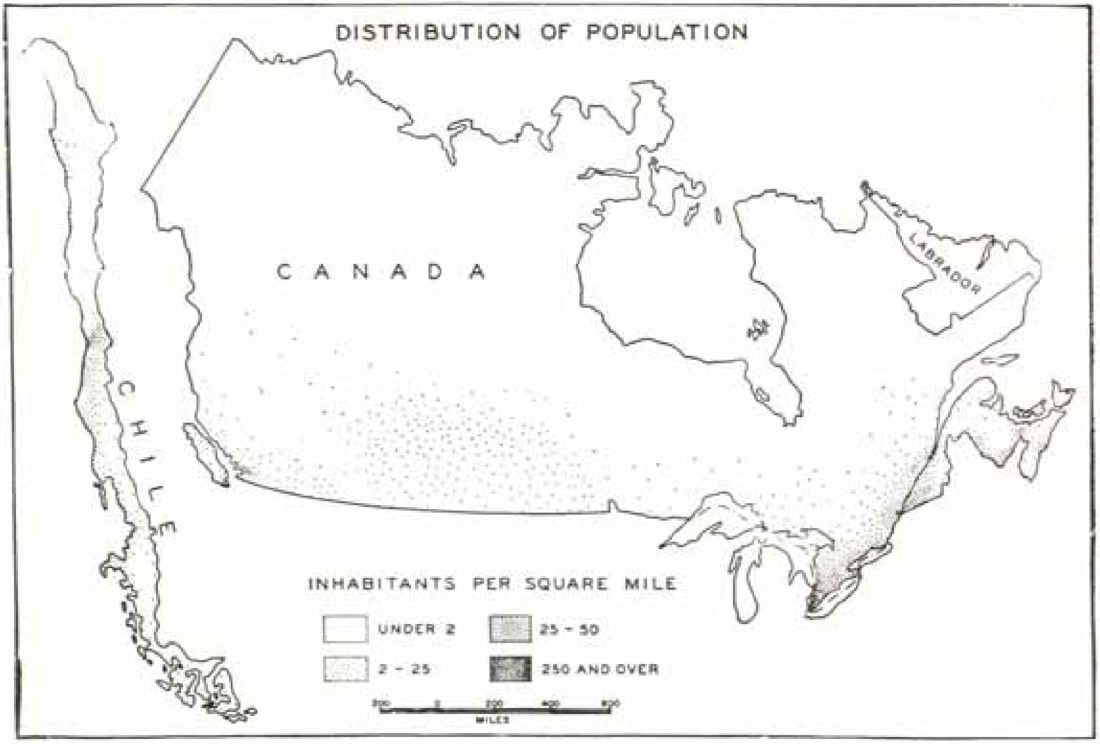


FIG. 255. Chile, attenuated in both area and ecumene; Canada, relatively compact in area, but with an attenuated ecumene, or inhabited area.

upheld slavery as an institution; others, with almost entirely white populations, considered slavery undesirable. During the Civil War, therefore, some parts of the state adhered to the North; others to the South. Though slavery has today disappeared, the former differences in economic interest and population composition still persist as effective forces to modify political beliefs. Thus attenuation still finds expression in the everyday life of Tennessee.

Compact and Attenuated Countries. Advantages of compactness and disadvantages of attenuation become even more pronounced for countries than for their political subdivisions. Chile, for example, despite a central government designed to offset sectionalism, differs so greatly in the extreme north and south portions that satisfactory governmental policies are difficult to formulate, and this situation is complicated further by the problems of communication which impose physical handicaps on effective administration. Moreover, in the event of war, the extended boundaries to be defended and the distances troops must be moved seriously handicap military operations and effective defense, thus jeopardizing national security. In a compact country, by contrast, these difficulties are absent.

The handicaps imposed by attenuation apply not only where the area delimited by the political boundaries is elongated, as in Chile, but likewise in countries where the ecumene or inhabited portion is attenuated. Thus Canada, though relatively compact with respect to the area included within her boundaries, suffers from attenuation, for her population is concentrated in a narrow strip more than 3000 miles in east and west extent, paralleling our International Boundary. Further, this narrow ecumene is discontinuous to the north of the Great Lakes. Canada therefore furnishes an excellent example of the multiplication of railroad mileage necessary, the differences in economic interests, views, and political viewpoints, and the difficulties of an administration satisfactory to all, in a country with a long and narrow inhabited area.

Size. Classification is designed to organize in-

dividual items of fact with a view to presenting them in their proper setting with reference to one another. When such organization is attempted, however, it becomes apparent that, in recognizing classes composed of similar items, certain borderline cases, difficult of proper assignment, will be encountered. Thus, in everyday conversation, we use the terms "rich" and "poor" to describe individuals in terms of their material possessions, though it is obvious that many persons cannot be properly classified under either of these two headings. Terms used in classifying areas on the basis of their space relationships are likewise comparative terms such as "central" and "peripheral"; "compact" and "attenuated", similar to the terms "rich" and "poor" in that they are without definite quantitative values. Thus, in much the same way that a given individual may be considered rich locally, but not by the standards prevailing over a larger area, a place may have a central location with reference to a small area, but be peripherally located with reference to the land masses of the world as a whole, or to one of their major subdivisions.

In classifying areas on the basis of size, the two contrasted classes recognized will be large and small, which likewise introduces the problem of the proper assignment of borderline cases: areas intermediate in size between the two extremes. This is the same problem encountered in listing areas on the basis of their locational and form characteristics, but it is neither disturbing nor important, for such borderline cases are intermediate in their characteristics resulting from size; and the fact that they are borderline cases therefore assumes importance, since it supplies the key to an understanding of their limitations imposed by size.

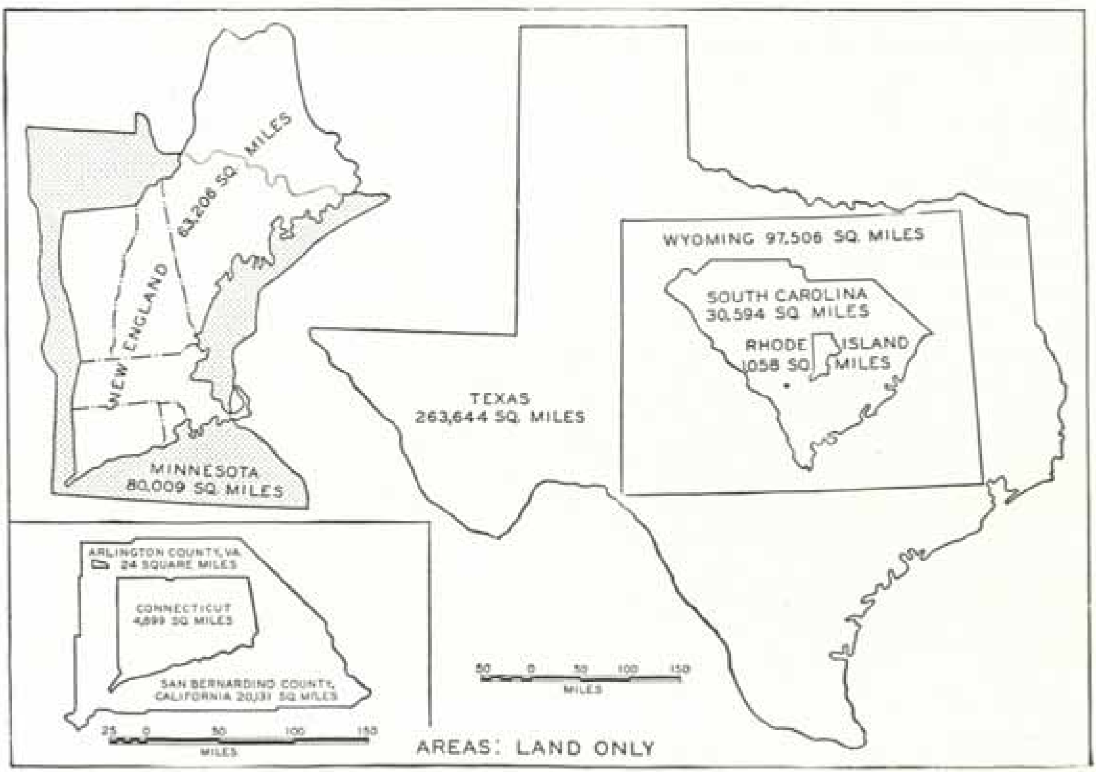


FIG. 256. *Lower Left:* A graphic representation of the range in size of our counties. San Bernardino County, California, the largest in the United States, is nearly two and one-half times the size of Massachusetts, and more than 800 times as large as our smallest county, Arlington County, Virginia.

Above and Right: A graphic representation of the comparative size of selected states. The area of each, given in square miles for land surface only, will assist in making effective comparison of their sizes possible. (Data according to the 1940 U. S. Census.)

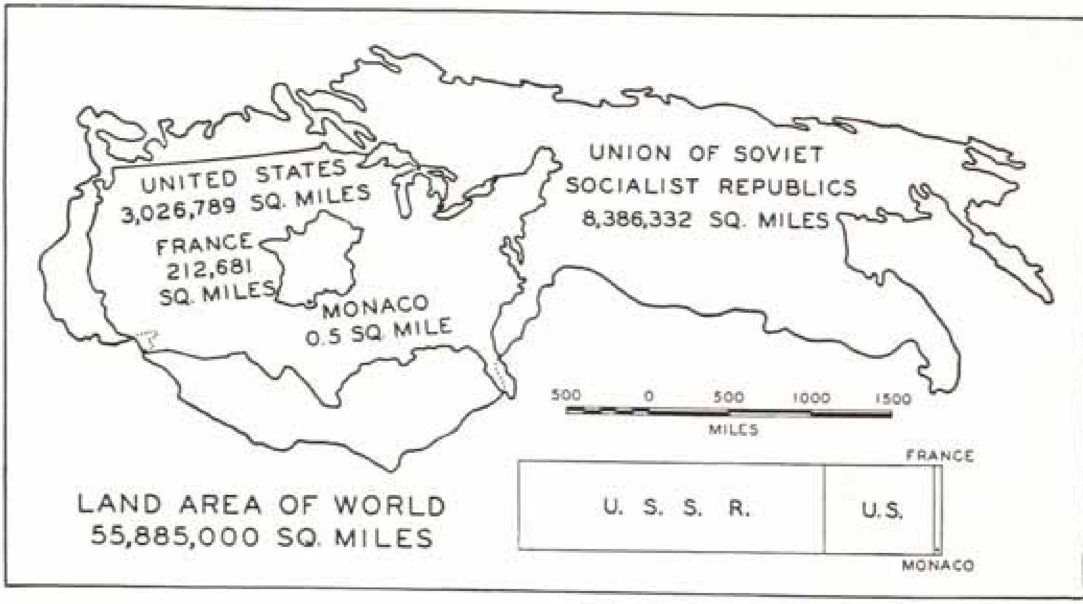


FIG. 257. A graphic representation of the comparative size of selected countries. The area of each, stated in square miles, should make effective comparison possible.

Expressions of Size. Mathematical expression of size is in some unit such as acres or square miles; the former used for relatively small tracts, the latter for those of greater areal extent. Thus the size of a farm may be stated in acres; that of a state in square miles. Such definite statements of size are useful for many purposes, but for others it is preferable to consider comparative rather than actual areas as expressed in some conventional unit. One reason for this is that, to the average person, expressions of areal extent in square miles or some other similar unit have little meaning, whereas a statement based upon comparison between a given area and one more familiar to the individual is much more informative. Thus, instead of thinking of New England as embracing 66,608 square miles, it is ordinarily more satisfactory to express its size in terms of the areal extent of some political subdivision with the size of which the individual is familiar. It is much more satisfactory for many purposes, for example, to think of New England as 79 per cent of the size of Minnesota, or of its relationship in size to that of your home state, than to know its area in square miles, and the same is true for areas other than New England. (See Fig. 256.)

Political Subdivisions	*Total Area in Square Miles (Land and Inland Water)*
New England	66,608
Rhode Island	1,214
Connecticut	5,009
Massachusetts	8,257
Vermont	9,609
New Hampshire	9,304
Maine	33,215
Minnesota	84,068

(U. S. Census, 1940.)

Characteristics of Small Areas. Small countries must necessarily have small or relatively small populations, correspondingly small amounts of taxable wealth, and limited resources, both in kind and amount. These conditions are unfavorable in times of peace and doubly so in times of national emergency. At an earlier date, some rather significant civilizations developed in small regions with limited but sufficient resources for that early period, but today these same areas could hardly be classed fairly as of great importance in world affairs since the handicaps of small size and the difficulties of adequate development tend to increase with increase in the complexity of Western civilization.

The greatest difficulty confronting small regions, especially if independent political units, is their lack of an adequate basis for varied opportunity and their forced dependence on other areas or countries for too large a fraction of their

necessities. The United States is the world's outstanding example of a compact country of large size which contains within its boundaries virtually everything necessary for attaining a high degree of development without the necessity for drawing on other parts of the world to satisfy vital needs. Yet even this country must at the present time depend largely upon outside sources of supply for natural rubber and a limited number of other raw materials. If this is true for our own country with its enormous and varied resources, it is inconceivable that a small country should afford all the raw materials of forest, field, and mine that are vital for modern industry. This lack of essential self-sufficiency, an unavoidable accompaniment of small size, always imposes a handicap. Under such conditions, economic pressure, as well as external aggression, tend to promote consolidations of the smaller political subdivisions into larger units, sometimes only economic, but often more complete. This was apparent even before the late war, which has hastened the process.

Small Counties. Too small size affects all types of political subdivisions adversely. It has been estimated that there are 3099 counties or their political equivalents in the United States. These range in size from 24 square miles for Arlington County, Virginia, to 20,160 square miles for San Bernardino County, California, the latter larger than any of the New England states except Maine, and nearly 40 per cent of the areal extent of the average state in this country. This great variation in size might be logical if it bore any relationship to population and wealth, but such is not the case for, in many instances, the small counties have small populations and little wealth, whereas the larger ones may be both wealthy and densely populated. For example, Los Angeles County, California, with its great wealth and population of over 3,000,000, has an area of 4080 square miles; by contrast, Carroll County, in north-central Kentucky, with but small wealth and a population only slightly in excess of 8000, has an area of 138 square miles, about one-thirty-first that of Los Angeles County.

The smaller counties of certain of our states are sometimes an inheritance from the past, when communication was poor and the smaller political subdivisions may have had some justification, but in other cases they have resulted from deliberate division promoted by would-be officeholders. Therefore we today have many counties with populations of less than 5000 which maintain complete sets of officials and carry on all county functions. Such small subdivisions increase taxes, decrease efficiency, and benefit no one except the holders of public office. Though their evils are widely recognized, local opposition too often prevents remedial legislation to correct the unfortunate situation.

Small States. Our states differ greatly in size, as do our counties. At one extreme is Texas, with an area of 267,339 square miles, larger than any country in Europe except Russia; at the other is Rhode Island, embracing but 1214 square miles, less than 0.5 per cent the extent of Texas. Such great variations in size have no adequate basis in geographic conditions, even though occasional boundaries may be geographically justifiable, but find their explanation in the almost accidental establishment of many state boundaries in the absence of a factual basis for their location.

Small Countries. Countries or independent governmental units likewise differ greatly in size. The Soviet Union, larger than South America; Great Britain with her possessions and dependencies, embracing an area greater than that of North America; and the United States, almost as large as Europe, together include within their boundaries nearly 50 per cent of the total land surface of the earth. It is no wonder that these countries are sometimes referred to as the "haves"; certainly they have preempted a large fraction of the earth's surface and their apparent approval of the present division of the world's resources is understandable. At the other extreme, and contrasting markedly in areal extent with these great holdings, are such countries as San Marino, a small republic with an area of 50 square miles and a population of 13,948; and, smallest of all, the principality of Monaco, only 395 acres in size, smaller than many a wheat farm in our western states. Even such a small, formerly independent country as Estonia, on the Baltic, was but 18,354 square miles in area, smaller than San Bernardino County, and only slightly more than one-ninth the size of California.

As pointed out earlier, the too-small country is handicapped by lack of the varied resources necessary for the complex industrial development which characterizes modern Western civilization. Within recent years, this has likewise made effective, independent defense of national boundaries

impossible, though this latter limitation may be less important in the future, in view of recent discoveries. Even though this may prove to be true, too many of the peacetime necessities must still be supplied from areas beyond the national frontiers, with the result that these small countries are hemmed in by man-made tariff and impost walls so high that, no matter where the economic sun may be in the sky, the small country will always lie in the shadow of one of these walls. The tariff may be an absurdity, as some maintain, but it is a fact which, absurd though it may be, must be reckoned with by all who consider the problems of the small country, not emotionally, but logically. The result of this handicap is that these small units become economic satellites of their larger and more powerful neighbors, on whom they must depend for such measure of economic success and security as they may achieve, except as federation occurs.

QUESTIONS AND EXERCISES

1. Under what conditions and for what purposes is mathematical location of places or areas valuable? Why is relative more important than mathematical location in its effect on areal potentialities and human activities?
2. Compare and contrast the relative advantages of locations in the various hemispheres. What is a great circle? How many such circles can be drawn on the earth's surface? What great circle marks the division between the Northern and Southern hemispheres? What is the boundary between the Eastern and Western hemispheres?
3. Why has London a better relative location than Auckland? Why is there a strong probability that the relative location of North America will improve in the future? What factors cause the development of Australia to be greater than might be expected in view of its peripheral location?
4. Why are the fauna and flora of oceanic islands limited in variety? Locate St. Helena and determine its ownership. Why did it make a good place to which to banish Napoleon? Locate the Galapagos Islands. What peculiar life forms, not found elsewhere, occur on these islands? Of what importance to this country were these islands during the late war? Where is Pitcairn Island located? By what country is it owned? Why does such a small island have considerable news value?
5. Why is it proper to speak of the oceans as "connecting the lands"? Why may a "central" relative location be different from a mathematically central location? Use New York City to illustrate.
6. Name the five largest cities of the United States in 1790. What was the population of each at that date? Why were they so small at that time? How do transportation facilities in most parts of China render the alleviation of famine conditions impossible? What effect has this lack of communication had on city growth?
7. What two factors operate to change the value of a given location for a city? Which operated to change the relative value of the locations of St. Louis and Chicago between 1840 and 1940? Why did St. Louis have a better relative location than Chicago in 1840, whereas that of Chicago is better today?
8. Under what conditions will an area be of strategic significance? What classes of areas may possess such significance? Why? Report on our holdings which protect the eastern approaches to the Panama Canal.
9. What have been the effects of attenuation in California and Tennessee? Why does attenuation jeopardize both economic welfare in time of peace and national security in time of war?
10. Why is Canada, properly speaking, attenuated, though that fact does not show to good advantage on an ordinary map?
11. For what purposes are mathematical expressions of areal extent of value?
12. In what respects are all small areas handicapped? Why did several early civilizations of importance develop in small areas? Why have they suffered a decline in relative importance at the present date?
13. What raw materials must this country import? From where are they secured? To what extent are we handicapped by this dependence on other parts of the world?
14. What is the range in size of United States counties? Is there any necessary correspondence between county size, wealth, and population? How did many of the small counties come into existence? Why are county consolidations difficult to arrange, even though desirable?
15. Report on the origin of the boundaries of your own state. Have these boundaries any valid geographic basis and, if so, what?
16. Why is it proper to speak of certain countries as the "haves"? What country has the largest of all national landholdings? The smallest? What is the extent of the holdings of each? What is the

basis for support of the population of the smallest country?

17. What is the size of a typical commercial wheat farm in the West? How does this compare with the size of Monaco? From what common handicaps do all the smaller countries suffer? Name and locate several of these small countries.

18. How is it possible for the very small countries to exist and preserve their national identity when surrounded by powerful and covetous neighbors? Illustrate by the Netherlands and Belgium. Why are these small countries at best but economic "satellites" of their larger neighbors?

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This reference supplies additional illustrations of the effects of location, size, and shape of areas on national ambitions and international relations.

PART FIVE. HOW MAN OBTAINS HIS LIVELIHOOD

Chapter Twenty-Eight

PRIMITIVE HUNTING AND FISHING POPULATIONS

Early Man and His Livelihood. Man's method of obtaining a livelihood is affected by both environmental opportunity and his stage of development, for each imposes limitations on the range of effective choice. Therefore, in certain areas, early man made his living in ways very different from those of the present. This was in part because of later alteration of the environment and increased opportunity resulting from such change, but in greater part because, for long after man appeared on the earth, his lack of knowledge prevented his making use of all existing natural opportunity, thus restricting his choice of a method of securing a livelihood.

To the earliest human populations of the earth, the immediate and obvious source of food supply was wild plant and animal life, which likewise afforded materials for clothing, utensils, implements, and shelters. Thus hunting, fishing, and the gathering of wild fruits, nuts, and other plant products furnished food and a supply of other products necessary for existence and the meeting of simple needs. Later, it was discovered that artificial propagation of some of the plants of forest and grassland, such as seed-bearing grasses and fruit-yielding bushes and trees, could be undertaken to advantage. This adventure in cultivation marked the beginnings of primitive agriculture, which gradually assumed increasing importance as a means of supplementing the food supply obtained by hunting and fishing. For thousands of years, therefore, man must have been a migratory collector, hunter, fisherman and, toward the last and in lesser degree, an agriculturalist.

Even today, certain less advanced populations still depend on hunting, fishing, and primitive agricultural production, leading a migratory or semimigratory existence. These populations may be found scattered from the equator to the margins of the polar ice sheets, but their numbers are everywhere few and the regions they occupy offer only slight attraction. In all areas of greater promise, man has made sufficient progress to have emancipated himself from the necessity of securing the means for his support in this unsatisfactory fashion.

These migratory hunting, fishing, and agricultural populations of the present have little influence on the world in which they live. Many of them are decreasing in numbers; some have already practically disappeared, either by absorption or as a result of the ravages of introduced diseases and vices or merciless exploitation. Such interest as attaches to them is largely because they afford illustrations of how man must have lived everywhere at earlier periods of time. Thus they not only supply excellent examples of direct and intimate dependence on the immediate environment, but contemporary illustrations of our ancestral life as well. In the following pages, a few selected population groups of this type and their methods of obtaining a livelihood will be described as illustrative of these facts. For the sake of variety, the groups chosen are from widely separated localities which differ greatly, though all have the common characteristic of possessing a repressive environment. Thus some of the populations are those of regions of polar cold; others, those of dry or desert areas; still others, those of the humid tropics, where it is too wet.

The Eskimos: Nomadic Hunters of High Latitudes. The Eskimos are inhabitants of the polar margin of North America, its bordering islands, the coasts of Greenland, and the extreme northeastern portion of Asia. Everywhere dependent almost entirely on hunting for a living, they are forced to turn to the sea for most of their food

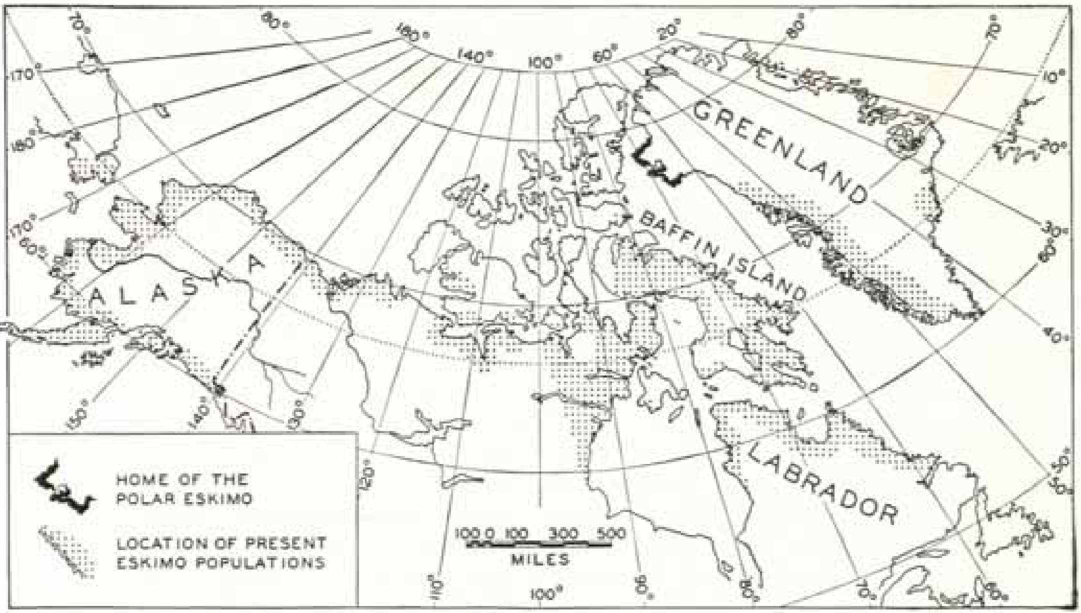

FIG. 258. Distribution of the Eskimo and the homeland of the Polar Eskimo, an essentially self-sufficient, primitive hunting population. Their homeland, shown in solid black on the map, is a fringing coastal strip, not covered by snow and ice throughout the year. This small population group of Polar Eskimo is the northernmost, as well as one of the most isolated in the world.

supply and to satisfy most of their other needs, for the resources of the region where they live are much too meager to support even their limited numbers by hunting on the land alone.

In many parts of the area at present occupied by the Eskimo, his former habits of life have been altered greatly by contact with white populations. Where this has occurred, with introduction of firearms and other goods of the white man, the Eskimo has passed directly from the Stone to the Iron Age. Native dress has been modified; new foods have been introduced; diseases, intoxicating liquors, and vices, formerly unknown, have worked great harm; and the Eskimo without some admixture of white blood is virtually nonexistent. Far to the north, however, on the west coast of Greenland between 76° and 79° North latitude, less than 1000 miles from the North Pole, a small group known as the "Polar Eskimo" live much as did their ancestors, and thus will serve as an example of an essentially self-sufficient primitive hunting population of the high latitudes.

The Homeland of the Polar Eskimo. The homeland of the Polar Eskimo is the highly indented, steep, and rocky coast, where small, discontinuous, narrow strips of flat land bordering the sea afford favorable locations for settlement. Inland, the enormous sheet of ice which covers the interior of Greenland to great depths is everywhere in sight. In places, it even reaches the sea and from its front great blocks break off as icebergs which float away and melt in southern seas. The homeland is therefore a narrow ice-free strip, bounded by steep, rocky cliffs and the inland ice on one side, and by a sea frozen most of the year on the other. During the winter, it is dark and very cold. The average January temperature is −13°F. and, even during the long daylight period of the short Arctic summer, the thermometer seldom registers as high as 50°F. at the hottest time of any day. Soils are thin, and in many places the bare rock forms the actual surface of the ground. Therefore vegetation is limited both in kind and amount, since few species of plants will grow under this combination of unfavorable conditions, and these not luxuriantly. There are no trees, but mosses and many flowering plants which can complete their active life cycle during the short summer period carpet the ground wherever there is a layer of soil not covered by snow. Thus the landward

hunting ground of the Eskimo is limited both areally and in resources, and he is forced to turn to the sea for most of his support.

The Nomadic Eskimo Hunter and His Shelter. In a land of such limited opportunity, the inhabitants must move from place to place, shifting location whenever game becomes scarce; consequently no great store of possessions can be accumulated to advantage. In summer, the Eskimos live in skin tents or "tupics," made of as many as 50 to 60 sealskins sewed together and stretched over a framework of poles. In winter, the tupic is abandoned for a more substantial and warmer shelter with walls of stone, roofed with flat slabs of limestone or slate, and covered with grass and turf. Over this are spread the skin tents used during the summer months. This winter dwelling, generally lined on the inside with sealskins, is called an "igloo." When covered by snow, as it is during the winter months, it looks somewhat as though it were built of snow. The house of snow, the "iglooyak," serves for only temporary or, at most, semipermanent use. When it is to be occupied for some time, it, like the igloo, is lined with sealskins.

With the coming of the long daylight period of the Arctic summer, temperatures rise and the important hunting season begins. Then the roof of the igloo is removed and the sealskin tents again supply shelter. Thus, during the summer, the walls of the igloo remain exposed to the elements, which perform the annual housecleaning for the Eskimo housekeeper. With return of long nights and low temperatures heralding the approach of winter, the igloo is reroofed and reoccupied.

Both summer and winter, the Eskimo lives near the sea from which most of his food is obtained, a site being selected where fresh water is available for drinking, where shelter from strong, cold winds is afforded by protecting cliffs, and where a good view of the sea, the more important hunting ground, is available. Heat for the house, both summer and winter, is supplied by lamps: shallow pans of soft soapstone in which the blubber from sea animals is burned. The wick, which the Eskimo housewife takes great pride in keeping trimmed so that it will give a good flame, thus indicating her competence, is made of twisted moss.

FIG. 259. Ak-a-ting-evah's tupic, his summer home. It is made of tanned sealskins, stretched over a framework of poles which have drifted to these inhospitable shores from distant lands with milder climates. The garments of the family are made from skins, this type of clothing being worn both summer and winter by the Polar Eskimo. (Photo by Donald B. MacMillan, Courtesy of the American Museum of Natural History.)

FIG. 260. Sip-soo's igloo in a winter village. Though built of stone, now that it is covered with snow, it looks somewhat like a snowhouse. The igloo is entered by way of a vestibule and a long tunnel which opens through a small hole in the floor of the igloo. During cold weather, the dogs sleep in the tunnel. (Photo by Donald B. MacMillan, Courtesy of the American Museum of Natural History.)

Food Supply of the Eskimo. The Polar Eskimo hunts summer and winter, both on the land and on the sea. On his success depends his life and that of his family, for all of his food is obtained from animals, which explains why the best hunters are so highly respected; they are good providers. Some of the food is cooked by boiling, but much of it is eaten raw and some of it is far from fresh, though in such a cold region food can be preserved for long periods of time if care is exercised in its storage. The Eskimo thrives on this diet, which would not seem attractive to us, and he does not appear to suffer from lack of the varied fare to which we are accustomed.

From the sea, the Eskimo obtains seal, walrus, narwhal, and beluga, the last a member of the dolphin family which sometimes attains a length of 10 feet. These animals supply not only meat and blubber but skins for some of the clothing as well. Land hunting furnishes caribou, Arctic hares, an occasional musk ox, and birds, which provide part of the food and, the last, some of the clothing, for underwear is made from bird-skins with the feathers worn inside. In open sea hunting, the kayak, a watertight canoe made of skins stretched over an interior frame, is used. In the deck there is an opening into which the paddler is lashed by a watertight joint so that he is able to ride the stormiest seas without danger and to right himself without shipping water if capsized. This is the most hazardous type of hunting, yet in this frail craft, operated by a double-bladed paddle, the Eskimo hunts walrus and other sea animals, which supply food and materials for his clothing and tents, during the summer months.

Clothing and Utensils of the Polar Eskimo. Clothing must be warm in this cold region and, since there are no plants which can be used, it is made of skins. Even the needles and thread used are supplied by animals, for the needles are of bone and animal sinew is used for thread. It makes very good thread, too, since it swells when wet, filling the holes made by the needle and thus keeping out water, highly important in this land of snow and ice. All skins are prepared for use by scraping and chewing, for there are no tanning materials in Greenland. This work, done by the women, is very hard on the teeth, which are generally worn down to the gums by the age

FIG. 261. Two Eskimo building a snowhouse or iglooyak. Constructed of blocks of hard packed snow, it makes a rather comfortable temporary shelter, but it would be but poorly adapted to permanent occupation. (Photo by Donald B. MacMillan, Courtesy of the American Museum of Natural History.)

FIG. 262. When the ice has melted or drifted away, the kayak is used for travel and hunting whenever the weather permits. Note how the paddler is lashed into the deck opening and the double-bladed paddle used to propel the kayak through the water. (Photo by Donald B. MacMillan, Courtesy of the American Museum of Natural History.)

of thirty. There are no changes of style in Eskimo land and both men and women dress much alike, all with a view to comfort and utility rather than appearance.

The hunter's weapons are likewise made from animal products. The bow is fashioned by splicing pieces of bone with sinew; snares for catching birds and other small game are also of sinew. Even the whip for driving the dogs, the beasts of burden of the Eskimo, has a lash of sealskin, and the sled used for transporting the hunter and his few possessions from place to place is made of bone and ivory, fastened by thongs.

Before contact with white men, every want of the Polar Eskimo—food, shelter, fuel, clothing, and utensils—was satisfied from the home area, plus material washed up on its shores; but, with the partial breaking down of the barrier of isolation, change is occurring. The gun has today in considerable part replaced the bow and arrow for hunting; steel needles, those of bone; and steel strips, the ivory runners of the sledges. Despite these minor changes, however, the Polar Eskimo still depends almost entirely on the home area for food, clothing, shelter, and fuel. He still leads an essentially self-sufficient existence, independent of the resources of distant lands. Just emerging from the Stone Age, he is still a migratory hunter.

Other Nomadic Hunting Populations of the High Latitudes. The Arctic shores of the Northern Hemisphere also support nomadic hunting populations other than the Eskimo. In northern Eurasia, for example, many of the Ostiaks and some of the Samoyedes of the Lower Ob depend on the animal life of land and water for support. In the high latitudes of the Southern Hemisphere, however, such populations are few and their numbers are limited. In Antarctica, the ice not only covers the land almost completely, but it even overflows to form a floating fringe of shelf ice in many places, thus rendering permanent primitive human occupation impossible. Only in Tierra del Fuego are environmental conditions even moderately satisfactory. There, the Onas of the main island depend on land hunting, principally of the guanaco; the Yahgans of the south, and the Alakalufs of the west, on the life of both sea and land. All three of these groups use the bow and arrow and, like the Eskimo, all are just emerging from the Stone Age. In common with most other primitive populations, their numbers are decreasing; of the original estimated 10,000, probably fewer than 1000 remain today. Advanced populations, it is true, may endeavor to preserve their own unfit, but seldom if ever the primitive population groups with which they come in contact.

Nomadic Hunting Populations of Dry Areas. In many of the drier, as well as the colder parts of the earth's surface, opportunity is too limited to tempt preemption by more advanced populations. Therefore the aboriginal inhabitants still retain relatively undisturbed possession, many of their former characteristics, and most of their earlier ways of obtaining a living. The Kalahari Desert of southern Africa is such an area, still occupied in its drier central part by a debased, nomadic people, the Bushmen, whose life will be described to illustrate that of a nomadic hunting population of dry areas.

The Homeland of the Kalahari Bushmen. The Kalahari Desert, the name of which is of Bechuana origin and means "salt pans," is usually considered to include about 140,000 square miles, essentially the political subdivision known as the "Bechuanaland Protectorate." Within this area, approximately 10,000 Kalahari Bushmen, divided into many small clans of a few families each, range from the marshes of the Okavango River and Lake Ngami southeasterly to the Limpopo River and, southwesterly, to the Nosob, with the greatest concentration in the better watered north, bordering the marshes of the rivers and depressions. Population, however, is everywhere sparse, for it requires much land to support a few inhabitants in this dry region.

The surface of the Kalahari is generally undulating and covered to some depth by soil, often white or red in color, though interrupted in places by rocky ridges and isolated kopjes or small hillocks. Part of the region is a waste of drifting sand, with dunes rising from 20 to 100 feet above the flat intervening areas, which range from 150 to 450 feet in width. In other places where soils are sandy, they are anchored by a scanty growth of grassy vegetation. Some of these dune sand belts, which attain a length of as much as 100 miles and a width of from 20 to 50 miles, make travel locally very difficult.

Temperatures are moderate to high throughout the year, January averages ranging from 85° to 90° F.; those of midwinter are about 60° F. Daily range is great at all times of the year, for

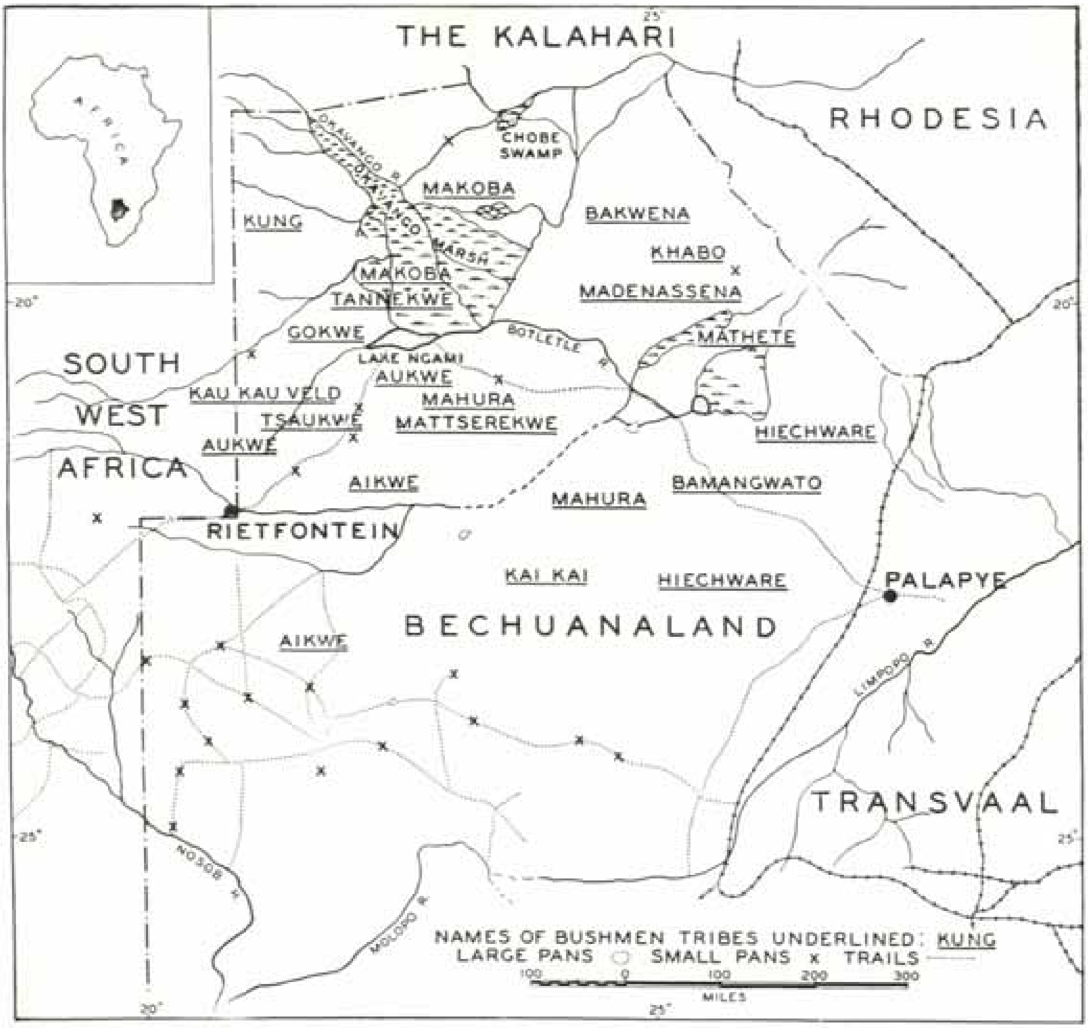

FIG. 263. The Kalahari Country, the home of the Bushmen. (Names and location of the tribes after S. S. Dornan.)

this is a desert area. In the heat of a summer day, the thermometer may register as high as 114° F. in the shade; at night, the temperature may fall to 50° F., or even lower during the winter. Further, rains are often accompanied by sudden drops of temperature of as much as 40 degrees. There are only two seasons: a long summer and a short winter. Heat is cruel in the former; cold often causes great discomfort during winter nights.

Rainfall is light, though the Kalahari, the "southern Sahara," is not so dry as its northern counterpart, the true Sahara. Near Lake Ngami, on its northern margin, the annual rainfall reaches 13 inches; in the south, near the Molopo River, the channel of which seldom carries water, precipitation drops to 8 inches or less, very little for this warm area. Further, there is great variability in the amount received from year to year. The weather is most disagreeable before the rains. At that time, there has been no measurable precipitation for perhaps 10 months or more; the winds, commonly strong and dust-laden during the heat of the day, are hot as if from a furnace; everything is parched and dead. Day after day it is the same. When the rains begin, the last of

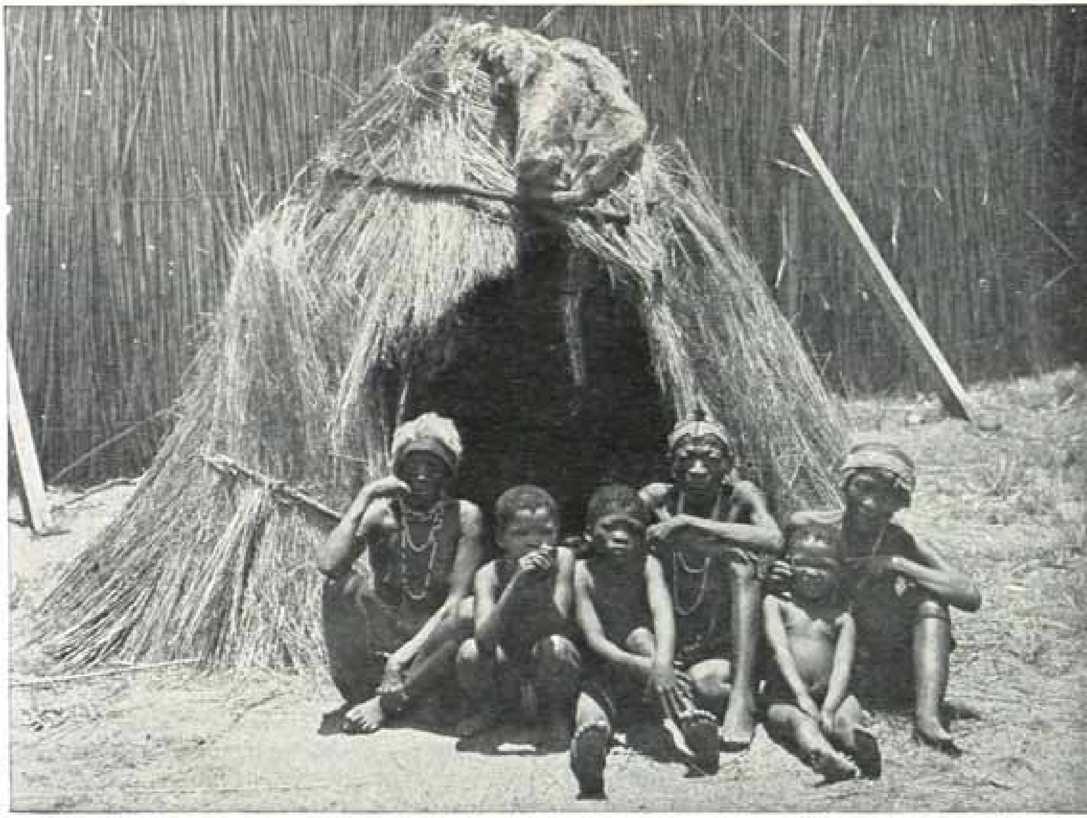

FIG. 264. A group of Kalahari Bushmen and their reed shelter. (Courtesy of the South African Railways and Harbours.)

December or the first of January, they are exceedingly violent downpours, as much as 2 inches of water often falling in one hour. By the end of February, the rains are over and the country is at its best, but health conditions are poor. "Pans," or shallow depressions, are now full of water and mosquitoes are everywhere. Malaria, blackwater fever, dysentery, and enteric fever flourish; pneumonia and, of late, influenza as well are common. The Kalahari is not a health resort during the wet season; at all times its climate is trying to whites.

With this amount and distribution of precipitation, river beds are dry throughout their length most of the year; in their lower portions, choked with drift sand, they may never contain standing water. Even in the better watered areas, they are only a succession of pools and contain little or no running water. Everywhere, therefore, but little if any of the water of the rivers reaches the sea. The playas or intermittent lakes and the pans contain water, generally brackish, for only a short time, during and after the rains; when they are dry, many of their beds are covered with incrustations of salt. Throughout the Kalahari, water supply is limited, difficult to secure in adequate amount and satisfactory quality most of the year, and often impossible to locate at the surface.

During the dry months of winter, the soil is often bare or the solid rock is exposed; during and after the rains of summer, by contrast, the ground is generally carpeted with vegetation, for many herbaceous plants spring up from tuberous roots at that time, thus affording a food supply for animals. In the south, the sparse vegetation is limited essentially to Bushman and meadow grasses, 2 to 3 feet in height, woody growths being almost entirely lacking. Farther to the north, however, there are dense thickets of acacia along the rivers and, in places, trees of some size.

FIG. 265. An old Bushman and child in front of a shelter built of reeds, with another child in the interior. One of the children is naked; the other wears a breechclout; the old man is clothed more completely and wears numerous ornaments as well. (Courtesy of the South African Railways and Harbours.)

In general, however, the ground is seldom covered solidly by vegetation, and in most places plant growth is sparse and always of drought-resistant types.

The Kalahari is a great game country, especially in the Ngami region and the Okavango marshes, immediately after the rains when water supply is abundant in the pans and the quickly maturing herbaceous growths afford an abundant food supply for grazing animals. The larger herbivorous animals found at this season include various species of antelope such as the kodoo and blesbok, the oryx or gemsbok, and the gnu or wildebeest; zebra; giraffe; and numerous others, all of which furnish food for the predators: lions, hyenas, wild dogs, jackals, and many more. Smaller forms of animal life such as rabbits, rats, mice, and bats are likewise numerous at this season, and birds frequent the area in enormous numbers, both those such as quail, grouse, partridge, ducks, and geese; and raptorial birds like eagles, hawks, vultures, and buzzards. Reptilian and insect life is also abundant and much in evidence, white ants in particular being a great plague, though one variety, the "Bushman's rice," an ant with a long body and a black head, affords part of the food supply of the native population. For a short time after the rains, therefore, it is a time of plenty for the Bushmen, for food is not difficult to obtain and water is easy to secure. But the wet season is short and, with its close, water supply is limited, the animals migrate with drying up of the pasturage, and existence in the Kalahari, even for the Bushman who knows it best, becomes difficult and precarious.

The Shelters of the Bushman. Since he is a migratory hunter, changing location frequently throughout the year within fixed clan or tribal limits to follow the game which affords most of the food supply, the Bushman can neither accumulate many possessions to advantage nor does he find it practicable to construct a substantial, permanent shelter. For protection from the weather, therefore, the Bushman uses caves, shallow holes, or a few branches stuck in the ground, either with or without a grass or skin cover. Often he may put up only a semicircular screen of brush, not more than 3 feet high, with a fire in the opening to raise the temperature and keep off animals. With such protection from the elements, he sleeps, curled up like a dog, in a hole scooped out in the ground, with his head toward the screen, his feet toward the fire. In the Ngami region, where reeds are abundant in the marshes, he may use reed mats to build crude huts or as a protection to windward in a natural rock shelter. During wet weather, he is miserable, for he has no adequate protection from the rain.

Clothing and Utensils of the Bushman. Clothing is scanty and made largely from the skins of animals. During the heat of the day, the men wear very little, often only a breech clout, a piece of skin threaded on a sinew or cord, passed between the legs, and tied in front to a cord around the loins. The women wear a piece of skin, hanging from the waist to the knees in front, and sometimes one in the rear as well, both secured to a cord around the waist. When two are worn, they

form almost a complete skirt. Heads are never covered, but skin or bark sandals are sometimes, though not generally, worn. These complete the daytime wearing apparel of the well-dressed Bushman, which is supplemented by numerous ornaments and, among the women, by the use of native cosmetics. At night, when it is colder, a kaross or cape made by sewing several skins together is worn by both men and women. Both smear their bodies with "bucher," a native ointment made from red or white clay, mixed with fat. This collects dust and, since never removed and bathing is unknown, it eventually forms a solid crust which is proof against the most persistent and effective of the insect pests, and a protection from the sun. Since all Bushmen are verminiferous and the sun is very hot in the Kalahari, this very obvious "rind," though otherwise objectionable, has a practical value.

Household utensils are limited to the shells of ostrich eggs and a few crude pots. The eggshells are used in halves as cups; the whole shells, drilled and plugged, for storing water. Practically all food is eaten raw, or, at most, half cooked by broiling over an open fire. Therefore few containers, other than for water, are necessary. Fire is obtained by use of "fire sticks." These consist of a drill of hard mopani or acacia wood and a piece of soft wood such as commiphora, on which the drill is rotated by hand until the powdered soft wood glows. Then dry moss, used as tinder, is added and fanned into flame by blowing. With this procedure, a fire can be kindled in from 5 to 7 minutes. Housekeeping arrangements in the land of the Bushman are thus very simple; the principal problem of the women is the securing of an adequate supply of water.

The weapons and tools of the Bushman include bows and arrows, knobkerries or throwing sticks, knives, assagais, fire sticks, and digging sticks. The hardwood bows, strung with sinew, are from 2½ to 3 feet in length; arrows are made of reeds, wound to prevent splitting, or of wood. They are tipped with stone, bone, or, occasionally, iron, with a barb of quill. Knobkerries or throwing sticks, made from a bush with a large root, are from 2 to 3 feet in length, with a head at one end as large as a man's fist. Stone knives, 5 inches in length, or of bone, as much as 9 inches long; and assagais or spears, 5 to 6 feet in length, are sometimes used but not commonly. The knobkerry, for use at distances of from 25 to 30 feet, and the bow and arrow, effective at distances of not to exceed 250 feet, are the principal weapons used in war and for hunting game. To increase their effectiveness, arrows are dipped in a gummy poison of great virulence, compounded from probably variable but not definitely known local ingredients. Large game is hunted with the bow and arrow or is caught in traps and pitfalls; the knobkerry or kibi is used only for killing smaller animals and birds, which are also sometimes snared. Digging sticks, used by the women for securing succulent tuberous roots of desert plants to supplement the diet of meat, consist of a 3-foot shaft of hard wood inserted through a hole drilled in the center of a round stone 4 or 5 inches in diameter. The end of the shaft protrudes 6 to 8 inches beyond the stone, which is wedged tightly in place and designed to give weight and leverage in digging.

Food Supply of the Bushman. The Bushman has no domestic animals save a few half-wild dogs, used in hunting; he cultivates no gardens or fields. His dependence for a food supply is mainly on the results of the chase and some fishing, supplemented by roots, tubers, and other wild plant growths, plus honey, when obtainable. Bushmen are famous trackers and hunters; their sight is extraordinarily keen and, to them, the veldt is an open book. Stalking of game has been developed almost to an art, for only the successful hunter and those dependent on him survive, and, to be successful, close approach to the quarry is necessary with the crude and ineffective weapons used. Sometimes game is run down and killed, especially if it has first been wounded. Bushmen have been known to follow a giraffe as much as 50 miles before securing the animal.

The Bushman is an omnivorous, voracious, and dirty feeder. He has been known to eat half a sheep at one sitting, becoming torpid after such an excess. All the larger animals, as well as the smaller, including insects, contribute to his fare. Ants and their eggs, the latter considered a great delicacy, and even lice from his own person are part of his diet for, like many other primitive people, the Bushman appears to prefer small parasites. Plant foods, gathered by the women and children, consist of berries, roots, and fruits, including the wild melon, the tsama, which supplies both food and drink, and thus makes travel a

FIG. 266. Kalahari Bushmen, men, women, and children. See Fig. 15 for a comparable group of men, women, and children, all characterized by the same emaciated facial features and protuberant abdomens, but otherwise well-shaped bodies. This apparent physical deformity is a result of diet, affecting both sexes and all ages alike. Note also the clothing of the women and children in both this view and Fig. 15. (Courtesy of the South African Railways and Harbours.)

possibility in many areas where it would otherwise be impossible. The Bushman is not particular whether his food is fresh or putrid and he appears to suffer no ill effects from such a diet. To him, for example, eggs ready to hatch are as good as though fresh. No provision is made for the future; times of plenty are times of feasting; those of food scarcity are marked by abstinence and near famine. The dry season is thus one of great privation, for most of the grazing animals migrate to better pasturage, and with them go the carnivora. During the dry season, therefore, with food supply inadequate and none laid by, the body of the Bushman becomes emaciated, literally a bag of bones. At such times, he may even be reduced to eating the ragged skins which clothe him, with the hope that they may allay his hunger. These periods of gorging of the Bushman, broken by many and prolonged ones of hunger, are enforced by his low stage of development, which makes storage of animal food impossible in this warm climate.

The Bushman and the Desert. The Bushman is a creature of the desert which is his home, specialized to cope with the environment of the area where he lives. Small, for the adult male is commonly less than 5 feet tall and the female less than 4 feet 6 inches in height, he carries no surplus fat. Often he is almost emaciated, though active and capable of enduring great hardship and privation, including going without food or water for long periods, for only those capable of such endurance survive to reproduce their kind. The responsibility of hunting, which supplies most of the food, falls on the men; on the women, that of grubbing up roots, gathering other plant parts, and securing a supply of water. Even on the march, the hunter is never burdened except by his weapons, the fire sticks, and his pipe, for he must watch for and be ready to pursue game. The women are the beasts of burden, carrying the few family possessions, in addition to babies, slung across their backs.

The scanty resource of the Kalahari preclude

the possibility of a dense primitive population with a considerable degree of social organization, cooperation, except of a few individuals and families, being temporary only. Intellectual advancement is slight though, within his immediate field of interest, the Bushman is highly observant and possesses considerable shrewdness. However, speculation about a life after death apparently lies outside of that field for, though the Bushman believes in evil spirits, supernatural interference with man's life on earth, and possibly even dimly in some future life, he has no concrete idea of God nor has he formulated any definite picture of a Heaven or Hell. In other respects as well, the intellectual life is on a very low level, as with other primitive hunting populations, among whom the struggle for a bare existence is too keen to allow much leisure for speculations which do not have immediate practical results, particularly in the form of food. The Australian blacks, a comparable migratory hunting population of desert dwellers, have been discussed in some detail in Chapter VI, and many others such as the Tehuelcheans and Gennakens of Patagonia, all of small and decreasing numbers, inhabit comparable dry areas.

Nomadic Hunting Populations of Tropical Forests. Primitive hunting populations not only maintain footholds in both polar and arid areas but in low-latitude rain forests as well. Thus, in the dense forests of the tropics, nomadic hunting populations are to be found, even today, living essentially as did their ancestors many centuries ago. These tropical forests extend as a discontinuous belt, roughly paralleling the equator, in South America, the islands off southeastern Asia, and in the Congo basin of Africa. The last of these three areas is the home of the African Negrillos, a pygmy population.

These African pygmies have been known since the days of Herodotus, who described them as "a nation of little men who wore garments made of palm leaves, and who left their cities and fled to the mountains on the approach of the invaders," but despite this long period of acquaintance they still remain one of the less well known of the population groups of the world, with the result that it is sometimes difficult to separate truth from fiction in descriptions of their ways of life.

The Homeland of the Achua, the African Negrillo or Pygmy. The African Pygmy is widely dispersed in scattered groups, which range over a wide zone of equatorial Africa extending from Uganda to the Gabon, mostly between 3° North and 3° South of the equator, with the groups most numerous in the Belgian Congo. Of them all, those of the Ituri Pygmies, who live in the dense forests of the eastern Belgian Congo bordering the Ituri River, about 1° 30′ North latitude, 29° East longitude, are the least affected by contact with other populations, including whites. These pygmy communities are at home in no particular area, for temporary abundance of game largely determines regional desirability and location, though preference is

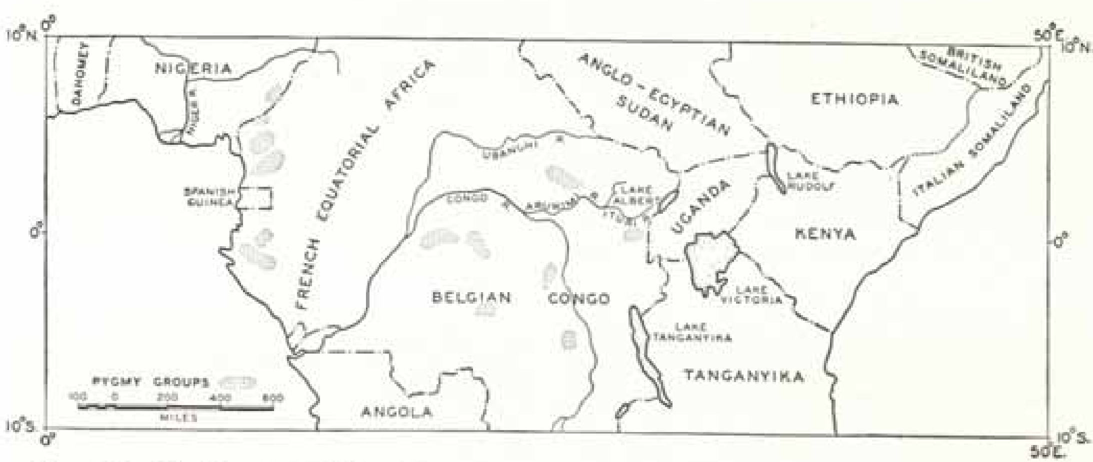

FIG. 267. The homeland of the African Pygmy, with some areas of marked concentration of these Negrillos. (After various sources.)

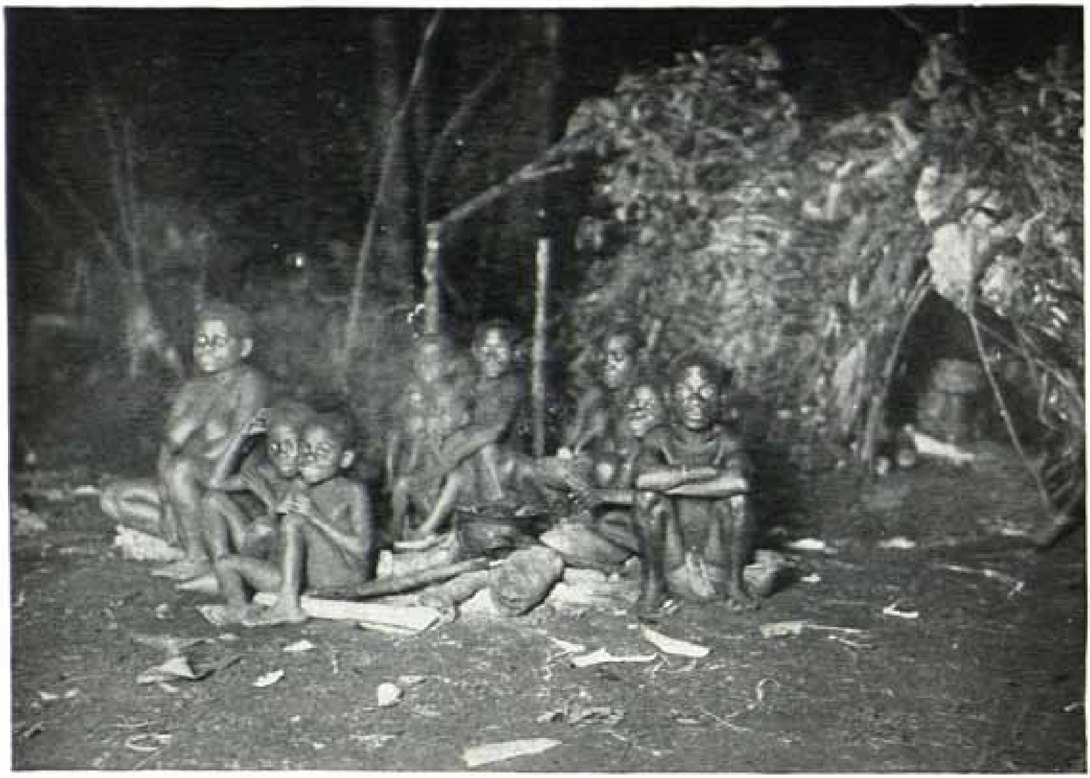

FIG. 268. A family of Pygmies of the Ituri Forest and their shelter, at the right. A meal of "wild spinach" is cooking in the pot over the open fire in the foreground. This pot, a square yard of dark cloth, and the bows and arrows comprise all their material possessions. (Courtesy of Martin Johnson.)

shown for areas where they are treated with consideration by other tribes and aversion to those where such consideration is lacking. This is despite the fact that the Pygmies are independent, considering themselves under no obligation to other populations, with whom relations do not extend beyond friendship and possible temporary alliance. Collectively called the "Achua," the different groups are known by various names, according to the language of the people in whose territory they happen to establish temporary settlement. Thus, in the basin of the Lunglulu, they are known as "Watwa"; in that of the Wabode, as "Balia"; in the districts of the central Congo, as "Batwa"; elsewhere, by other names.

The homeland of the African Pygmy is one of moderate elevation and slight relief, for elevations range mostly between 1000 to 1500 feet. Soils are thick, but like those of rainy tropical areas elsewhere, they are of low fertility and only temporarily productive under cultivation. The climate is equatorial in character; temperatures are uniformly high throughout the year. Thus, though they almost never rise to 95°, and but seldom as high as 90° F., the heat is very trying, for the annual range is less than 5 degrees and, even at night, it is not cool. Further, humidity is continuously high. This is not caused entirely by the amount of precipitation, which normally does not exceed 60 inches materially, and is in but few places as much as 70 inches, but results from the fact that rainfall is distributed throughout the year, so that it is excessively damp at all times. With a yearly total of approximately 65 inches, for example, rainfall commonly exceeds 3.5 inches even in the driest month; during the height of the rainy season, it may be as much as 10 inches. These climatic conditions favor growth of a dense, tropical forest, characterized by varied growths, with an equally diverse fauna or animal population. These are the environmental condi-

tions of the homeland of the African Negrillo of the Congo Basin.

Shelters of the Pygmies. The frequent shifting of location by the Pygnies, made necessary by primary dependence on wild plant life, fishing, and the chase, prevents establishment of permanent villages and makes construction of substantial structures undesirable, especially since they are rendered unnecessary by continuously high temperatures. The shelter of the Pygmy is, therefore, very crude, consisting of a beehive-shaped hut, about 7 feet in diameter and 4 feet high, with a small hole or opening about 1½ feet high near its base, through which he crawls on all fours. These huts are constructed of branches, each of which is stuck in the ground at both ends so that it forms a semicircle, the mesh formed in this manner serving as a framework for a covering thatch of leaves. The average temporary village is composed of from 10 to 12 of these huts, though occasionally the number may be as many as 30.

Clothing and Equipment of the Pygmies. Climate does not necessitate much clothing; in fact, often none is worn. At the most, it is limited to a strip of bark cloth or skin around the loins for the men, or a bunch of leaves, changed frequently, among the women. Even ornaments are few in number. The huts have scant furnishings. A rectangular bed of branches, supported a few inches above the wet ground by four stakes, one at each of its corners; a small number of crude clay pots in which spinachlike growth and bananas may be cooked; and a few gourds complete the household equipment. Weapons used include the bow and arrow and a short, light spear, the former used even for hunting the elephant, which is killed after being first blinded. Whether the

FIG. 269. A typical Pygmy of the Ituri Forest with his bow and arrows, and his shelter in the background. He wears no clothing except a breechclout. Hanging from a cord around his neck are the whistles used to imitate bird calls, and to enable him to keep tracks of his fellows, when hunting in the forest. (Courtesy of Martin Johnson.)

arrows are tipped in poison appears to vary from group to group, and possibly from time to time as well. South of the Congo, the Batwa at least are reported to use poison when hunting the elephant.

Food Supply of the Pygmies. The Pygmies have no domestic animals, not even dogs, and they probably never till the soil, dependence being wholly on hunting, fishing, wild forest growths, and the gardens of their larger native neighbors. They are expert hunters, capturing and killing even the largest animals such as the elephant, and gorging themselves to repletion after such a kill. As an illustration of their abnormal appetites, despite their small size, a Pygmy has been known to eat 60 bananas at a meal, besides other food. In addition to the larger animals, they are partial to white ants, bee grubs, larvae of beetles, and honey. They are likewise skillful fishermen, landing large fish with no equipment other than a cord baited with a piece of meat, but without a hook. From the forest, they secure wild beans, mushrooms, and other wild plant foods. They are particularly fond of bananas, obtained by barter or plunder of the gardens of neighboring tribes. In general, this barter is a one-sided transaction, with the Pygmy deciding that it is desirable and fixing the price to be paid, for it involves no more than appropriation of the bananas and leaving in their place what is conceived to be their value in the form of meat or some other commodity. Vegetables are sometimes eaten raw, sometimes cooked; meat is broiled over an open fire until it is dry. The Pygmies are not cleanly in their personal habits nor discriminating as to either the type or condition of their food, a characteristic which they share with most primitive peoples.

The Pygmy and His Forest Environment. The African Negrillo is the smallest of the pygmies, his average height being only about 4½ feet, with many adult individuals not more than 3 feet tall. Well proportioned, his average weight is about 75 pounds, with some adults weighing as little as 50 pounds. Despite his small size and weight, he is strong, fearless, and daring, but he does not like water and can seldom swim. He is an adroit climber, highly desirable in his forest environment, grasping small branches between his great and first toes to aid in his progress at the upper levels.

It is not surprising that the Pygmy is keenly observant, for his daily food and his security are dependent on excellence of sight and, brought into close and constant contact with the dangers of the bush as he is, his safety is ensured only by constant vigilance. In his forest home, the Pygmy is shy, his adroitness in flitting from tree to tree noiselessly and without exposing himself, making him difficult to locate; in captivity, he is fearless and defiant. When he considers he has been treated unjustly, he is exceedingly vindictive but, in general, his contacts with other native peoples are friendly, in considerable part because of their desire to avoid incurring his ill will.

His memory is excellent; his powers of mimicry great; and, by many, the Pygmy is rated as naturally intelligent. However, his intellectual life is lived on a rather low plane. He has no regard for time, no records or traditions of the past, no religion, no belief in a life after death, but a vague belief in devils. He has no laws and no hereditary chiefs, individuals adhering to the successful hunter in the small village. The life the Pygmy leads permits little in the way of diversion, but he enjoys dancing, in which he indulges at every opportunity. Despite his adaptation to the forest environment in which he lives, the Pygmy is destined to extinction unless protected, for he cannot hope to cope effectively with the new conditions introduced by the arrival of white populations.

Similar primitive hunting populations are known for other tropical forest areas, some, like those of the interior of New Guinea, being pygmies; others are of more nearly normal size. All live essentially the same type of nomadic hunting life; all are of small and mostly decreasing numbers; all tend to disappear completely when more advanced populations encroach on their territory, introducing conditions which these savages, still in the Stone Age of development, cannot meet effectively.

QUESTIONS AND EXERCISES

1. How does man's stage of development affect his choice of a means of obtaining a livelihood? Illustrate by examples.
2. Why did man first depend on wild life, plant and animal, for his support, and not until much later engage in even the most primitive agriculture? Why was such dependence unsatisfactory?
3. Why do present migratory hunting, fishing, and agricultural populations have but small influence on world affairs? Name several population groups of this type and state where they live.
4. Locate the homeland of the Eskimo. Locate that of the Polar Eskimo. Describe the physical environment of the homeland of the Polar Eskimo.
5. Describe the various shelters of the Polar Eskimo. What sites are chosen for their location? Why are tents satisfactory during the summer months of these high latitudes? Why is the house of snow used for temporary occupancy only?
6. Upon what does the Polar Eskimo depend for food? For his drinking water supply? Why is the sea rather than the land the more important hunting ground? During what season of the year is most of the hunting done? Why?
7. Describe the clothing of the Polar Eskimo. How has contact with whites modified the life of the Polar Eskimo?
8. Name some migratory hunting populations of the high latitudes of the Southern Hemisphere whose life is similar to that of the Polar Eskimo.
9. Describe the homeland of the Kalahari Bushmen in respect to topography, soils, climate, drainage, vegetation, and animal life. How do conditions vary with the seasons? Why? During what months would the summer season of the Kalahari occur? Why?
10. Describe the shelters of the Kalahari Bushmen. Why are more substantial structures impracticable, despite the unsatisfactory character of those in use?
11. Describe the clothing worn by the Kalahari Bushmen. What is the objective of the use of "bucher"? What are the principal household utensils of the Kalahari Bushmen and for what is each used? How does the Bushman kindle a fire?
12. What weapons does the Kalahari Bushman use in the chase and in war? With such weapons, why is it necessary that he be an expert stalker if he is to kill game?
13. What affords the food supply of the Kalahari Bushmen? Why does its adequacy vary so greatly at different times? Why is no provision made for periods of food scarcity?
14. Describe the physical appearance of the Kalahari Bushman, and discuss his intellectual development and characteristics.
15. Why are the too-cold, the too-dry, and the too-wet, or heavily forested tropical regions, still the home of nomadic hunting populations?
16. Locate and describe the homeland of the African Pygmy.
17. Describe the shelter and clothing of the African Pygmy. List his household equipment and describe his weapons.
18. Describe the food supply of the African Pygmy and state how it is obtained. Why do the other native populations submit to the enforced barter imposed by the Pygmies?
19. Describe the physical and intellectual characteristics of the African Pygmies. Why might such characteristics be expected in their forest environment?
20. Why are all nomadic hunting populations of the present few in numbers? Why are these numbers generally decreasing?

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Chapter Twenty-Nine

THE GRASSLANDS AND GRAZING: NOMADIC AND COMMERCIAL

Nomadic Pastoral Populations and Their Migrations. Nomadic pastoral populations are dependent on flocks and herds which are grazed on various types of relatively sparse native vegetation and moved frequently, with depletion of the pasturage. Thus both the number and kinds of animals differ from place to place, and the number in any single area, from season to season, with variation in water and food supply. In general, sheep and goats are more important where pasturage is poor; cattle, replaced occasionally by other animals such as the yak of the high plateaus of central Asia, where it is better. Horses and donkeys are also common, furnishing transportation and some food; likewise camels in hot, dry areas; and reindeer in the Arctic. Though approximately 10 per cent of the earth's land surface is inhabited by pastoral nomads, who live in all except the highest and lowest latitudes, their present numbers are small and their relative importance slight, for the areas they occupy present only limited opportunity.

Nomadic herders must move their animals frequently, for pastures are poor at best and soon exhausted. Thus some daily or weekly shift of location is necessary and, with the change of seasons, migration for greater distances, sometimes between lowland and highland. In northern Africa, for example, on the northwestern border of the Sahara, the nomadic pastoral tribes move into the desert during the winter, when there is some rain and scanty pasturage, but retreat to the Atlas Mountains with the coming of the hot, dry summer months, when water becomes scarce and lowland pastures poor. Similar migrations occur on the desert margin of the Sudan, the plateau of Iran, in Arabia, and elsewhere. Though there is no individual or group ownership of land in the ordinarily accepted usage of the term, these migrations are within roughly fixed tribal limits, established by long years of custom.

The Material Possessions and Life of Pastoral Nomads. Pastoral nomadism imposes restrictions on the quantity and variety of material possessions, which cannot be numerous and must be obtained largely from animal products or by limited barter. Food, therefore, is mostly of animal origin: milk, cheese, and meat, and possibly tea or some other beverage obtained by exchange. Similarly, the equipment, even the shelter, is made from hides, skins, or wool. Despite the importance of the animals as the source from which most of the material wants are supplied, livestock, in the absence of controlled breeding, tends to be of low grade, with some exceptions in the case of horses and camels.

A life of hardship and privation is the common lot of the pastoral nomad. Food is never overly abundant and always limited in variety; sometimes food scarcity or even famine conditions may occur. Goaded by hunger and necessity, these nomads formerly raided their more fortunate neighbors to secure what their immediate environment denied. In some cases, they even overran and conquered extensive lowlands of greater promise, sweeping over the plains of China, India, and western Europe from the grasslands of central Eurasia, often only to disappear almost completely with the passage of time through absorption by the more numerous inhabitants of these more favored areas. Such great migrations, possibly set in motion by a series of unusually dry years, are no longer possible, the pastoral nomads of the present being restricted to guiding, freighting, trade, and possible occa-

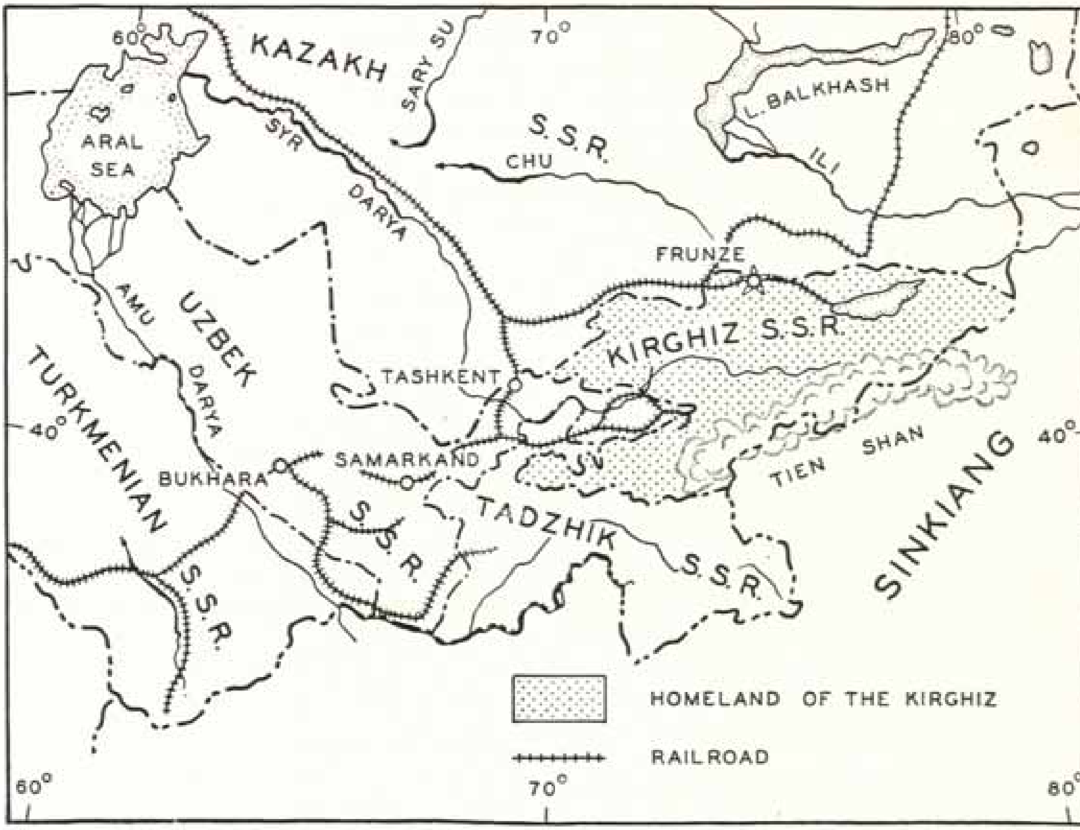

FIG. 270. The Kirghiz S.S.R., the homeland of the Kirghiz, is a land of diverse topography and great areal extent, embracing 75,950 square miles of territory which supports a population of approximately 1,500,000 persons. Isolated from other areas for many years, and still poorly served by rail lines, nomadic herding was long the only economic activity of importance. Of late, however, highly mechanized collective farming has supplanted grazing in some parts of this grassland area, though flocks and herds are still driven to mountain pastures during the summer, as in the past.

sional pillage of caravans to supplement the meager living they are able to secure from local resources.

The mode of life of pastoral nomads, which for so long made them a serious, continuing menace to sedentary populations of neighboring areas, no longer holds any threat. This is because technological advances not only enable other population groups to meet their aggression successfully, but even to assume the aggressive. Therefore, although in the past the nomads harassed their more numerous, less warlike neighbors, they have, except in rare instances, been retreating for many years before the advance of commercial grazing and dry farming. Often, though not always, this retreat has been accompanied by a decrease in their numbers. Both commercial grazing and agriculture, however, have already pushed so far into the drier parts of the world, the latter possibly even too far in some localities, that most of what remains of the former domain of the pastoral nomads will probably remain in their possession, for it does not offer opportunity which tempts populations with higher standards of living.

The Kirghiz, who live on the high plateaus of central Asia, have, until rather recently, been entirely dependent on nomadic herding for support, moving their flocks and herds considerable distances with the changing seasons. Though partial removal of the former isolation has altered their ways of life to some extent, pastoral nomadism still persists in the area where they live. Therefore this population group will be described

to illustrate how such nomads live and make their living.

The Homeland of the Kirghiz. Like other population groups of a similar, relatively low stage of advancement, the Kirghiz, who were formerly dependent almost completely on nomadic herding for support, long lived a life of comparative isolation, for their homeland is located in the heart of the great land mass of Asia, far from the sea. To its south are the great deserts of Sinkiang or Chinese Turkestan and the bleak plateau of Tibet; to its east and west are other dry regions. Only from the north is approach relatively easy; even there it is rather difficult. Surrounded as their homeland is by areas of limited opportunity, most of the contacts of the Kirghiz in the past have been with other pastoral nomads: Mongols and Turkomans. Only on the north have they been in even limited touch with more advanced population groups. It was, in fact, this isolation which made it possible for pastoral nomadism to persist for so long in the land of the Kirghiz. This older isolation is disappearing, however, and this has already modified ways of life materially, with additional change a strong probability.

The topography of the land of the Kirghiz is varied in character. The apparently boundless plains of the north give way gradually to low hills which increase in height to the south as the northern borders of the plateaus, of which they form the dissected margin, are approached. The surface of these plateaus lies at elevations of from 8000 to 12,000 feet, and they are hemmed in by lofty, snow-covered mountains, the Tien Shan, in which glaciers head. All, plain, plateau, and the lower slopes of the mountains, afford pasturage for the flocks and herds of the Kirghiz at some season of the year.

Water supply is always a critical factor in the life of pastoral nomads. Therefore the rivers, characterized by great variability of flow, and the numerous springs of the mountain border, are very important to the Kirghiz. When such sources of supply in the drier lowlands are few in number, occupation is handicapped; during the summer months, in fact, large stretches of such lowlands are uninhabitable. Lakes, both salt and fresh, play a less important part in the life of the Kirghiz than do the springs and streams, except that, when dry, beds of shallow saline lakes may supply salt.

Everywhere far from the ocean and cut off from moisture-bearing winds by topographic barriers as the area is, precipitation is light though, fortunately, most of the small amount falls during the summer months. Even with this favoring condition, the lowlands are so poorly watered that they afford no pasturage in midsummer. Precipitation increases at greater elevations, however, and the snowfall of the highlands is so heavy that flocks and herds cannot be grazed during the winter months, at which time of the year winds are generally strong and always bitterly cold. The summers of the lowlands are equally trying, for they are very hot. Those of the highlands, though sometimes rather cool and wet, are not generally disagreeable for, though frost may occur even in July, many of the days are bright and sunny.

The character of the vegetation varies with elevation. The plains are treeless, grassy steppes, with possibly a few willows along stream courses. At elevations of approximately 6000 feet, however, coniferous forest growths make an appearance, as shown in Fig. 271. At elevations of 8000 feet or more, temperatures are too low for trees and grass again predominates, to be in turn succeeded by mosses and lichens as the snow line is approached. In general, therefore, the domain of the Kirghiz is grassland, with only limited forest growth in a few favored localities.

Economic Activities and Migrations of the Kirghiz. Since grazing, based on opportunity afforded by natural grasslands, constitutes the basis for support, the Kirghiz have flocks of sheep; herds of cattle; and beasts of burden such as the horse, yak, and the two-humped or Bactrian camel, the last indicating that this is a rather dry region. Inasmuch as pasturage is scanty at best, these animals must be moved frequently. During a given season, this shift of location is for short distances only. In summer, however, pastures of the lowlands become poor, but those of the plateaus have lost their snow cover, the grass is exposed, and its growth is rapid. Therefore the animals are then moved from the dried-up and poor pastures of the lowlands to the plateaus, a much greater distance, for the three or four midsummer months. As winter approaches and temperatures lower, the flocks and herds are driven into sheltered valleys, and finally out on the plains again for the months of midwinter.

FIG. 271. Kirghiz migrating to summer pastures of the plateaus and lower mountain slopes, where scattered coniferous growths occupy the better watered portions of the hillsides which border the flatter grassland in the foreground. Note the beasts of burden: horses, and the two-humped or Bactrian camel; and the other livestock. See also Fig. 16. (Courtesy of Sovfoto.)

This type of seasonal migration is sometimes referred to as "transhumance."

Such extensive migrations necessitate careful organization, for the fate of thousands of animals, the basis for support, cannot be left to chance. Adequate provision must be made for the journey. Routes must be laid out; halting places must be determined; a water supply must be assured at each camp site; and other steps taken to ensure smooth functioning of the movement. Since the journey cannot be planned precisely in all details, because of seasonal vagaries, a certain amount of leeway is necessary to provide for unexpected contingencies. This may even make necessary some provision against an unexpected shortage of forage, as well as of water.

Because of the generally scanty pasturage, flocks and herds must be widely dispersed, not only during but both before and after the migrations. Thus it is seldom that large groups of pastoral nomads assemble in a limited area. In Biblical times, "Abraham and Lot pastured their herds at opposite sides of the horizon." Similarly, it is only at infrequent intervals, and then for short periods of time, that large numbers of Kirghiz herders foregather in a limited area.

The Life of the Kirghiz. The life of the Kirghiz herder is one of much movement, considerable hardship, and without most of those aspects which we consider desirable. Some of the men watch the sheep; others on horseback care for the herds and hunt stray animals and predators, which take a significant toll of the vitally important domestic animals each year. Milking and all routine work is done by the women; the men assume only those tasks involving considerable exertion, hardship, or danger, but with long periods between them when little effort is required.

When in camp, the Kirghiz erects a felt tent,

or yurt, with a cover made from the wool of his sheep. First a circular lattice of willow, 12 to 15 feet in diameter, is set up, with light poles converging from its top toward a circular opening in the peak of the structure. Over this framework, a felt cover is stretched tightly to form a warm, water-tight exterior which keeps out cold and rain. The circular opening in the roof serves as an outlet for smoke. When moving, this tent can be dismantled in a hour. Then the lattice, tent poles, and cover are lashed on the back of a camel or some other beast of burden for movement to, and erection at, a new camp site near other pasturage.

Since movement is frequent, household furnishings are simple and few in number. There is no furniture, rugs taking the place of chairs, tables, and beds. Milk, butter, and cheese, the food supply, are kept in partly cured sheepskins rather than in fragile earthenware containers. There are no stoves, but only open fires, for which dried grass and dung are used as fuel. One wooden bowl to hold sour milk, soup, or meat serves the whole family at mealtime, and forks and spoons are unnecessary, for all dip into this common bowl with their fingers to secure the food.

The diet of the Kirghiz is limited and without variety: mostly sour milk, cheese, and meat. Vegetables are practically unknown and even meat is not eaten regularly, for many animals are lost to predators and some must be used for barter, which limits the number available for food, if flocks and herds are to be kept up in numbers. Milk, always used sour, is the staple food Sometimes it is made into butter and cheese,

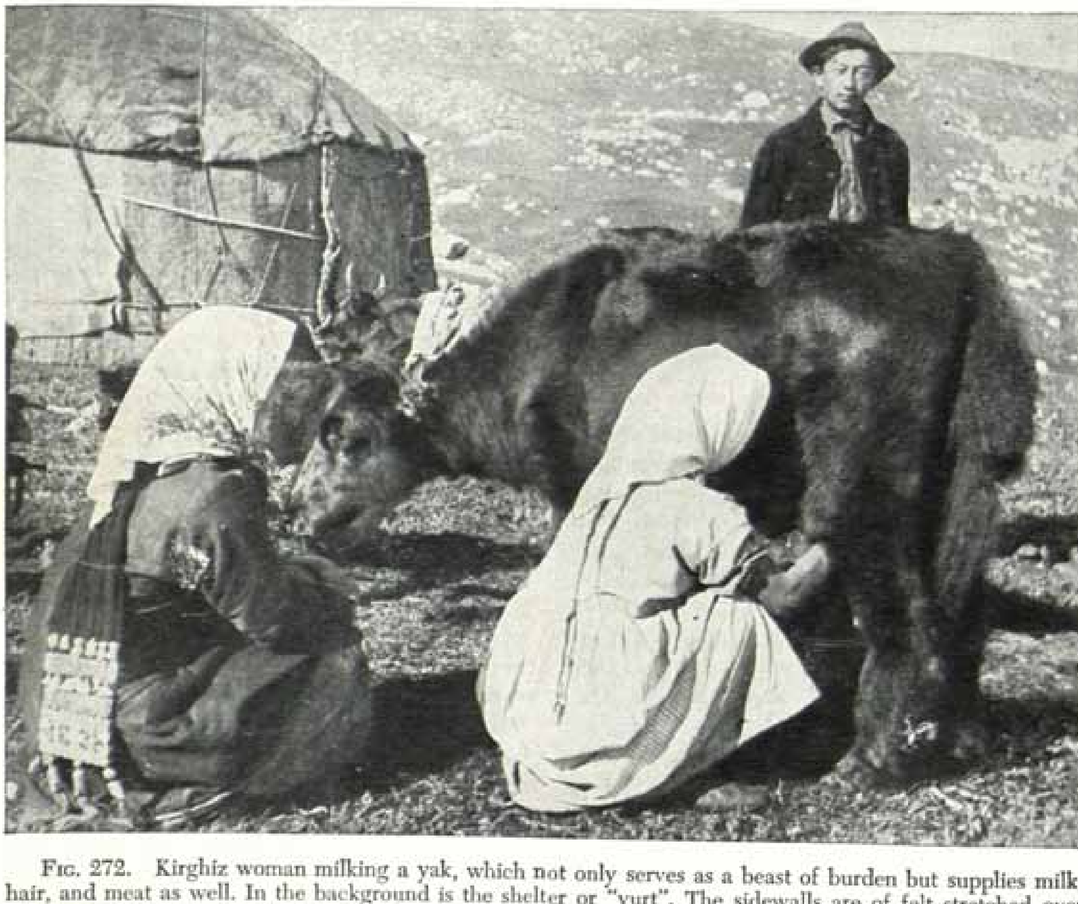

FIG. 272. Kirghiz woman milking a yak, which not only serves as a beast of burden but supplies milk, hair, and meat as well. In the background is the shelter or "yurt". The sidewalls are of felt stretched over a lattice of willow, which shows at the bottom of the structure; the dome-shaped roof, supported by a framework of poles, has a similar cover of felt. See also Fig. 16. (Courtesy of Sovfoto.)

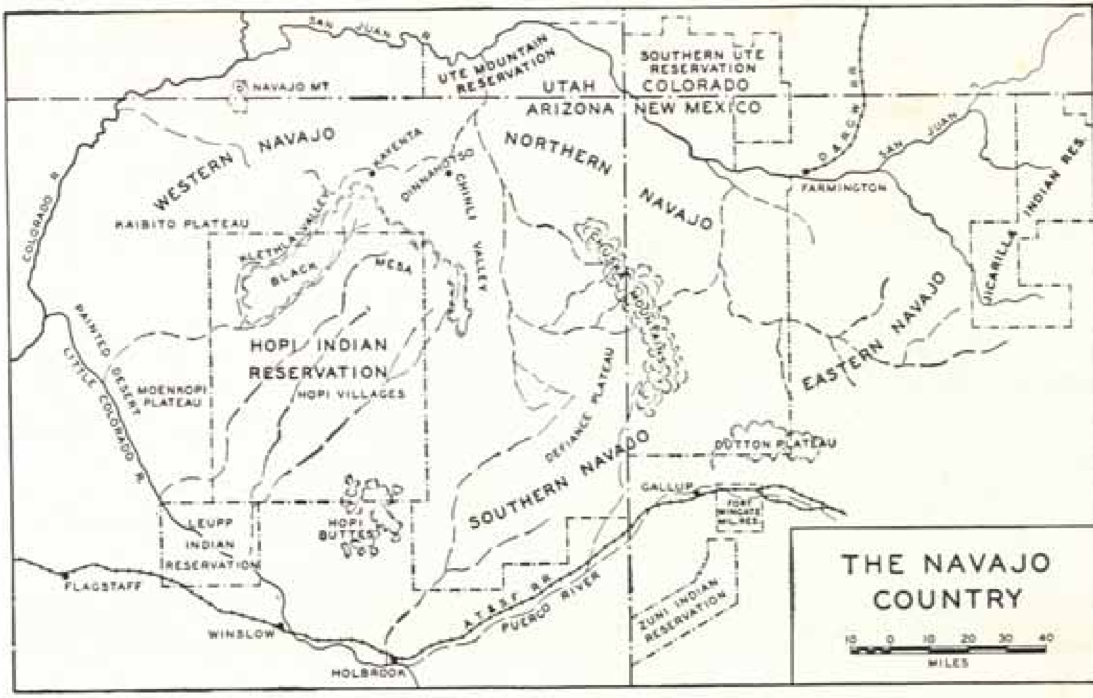

FIG. 273. The Navajo country of southwestern United States.

which may be kept for long periods of time. Bread, both fried and baked, and made from flour obtained by barter, is considered a great luxury.

The Kirghiz also meet their clothing needs from their flocks and herds, using wool and skins for a variety of purposes. Both men and women wear warm, padded garments and high boots at all seasons. In addition, the men wear sheepskin caps, and both sexes, sheepskin coats. Besides the wearing apparel made from animal materials, the women fashion headdresses of cotton cloth. The need for such items as cloth leads to some trade by barter, but such exchange is restricted to a very few articles: flour, cloth, guns, ammunition, and a limited number of others, for the wants of the migratory Kirghiz which cannot be satisfied from local resources are few in number.

Today, however, the older isolation which fastened pastoral nomadism on the Kirghiz has disappeared in part. As a result of this, and under governmental encouragement, mechanized agriculture has already invaded the domain of these pastoral nomads and combines harvest grain crops on the state-operated farms or collectives, located in areas where only flocks and herds grazed a few years ago. Today, as well, industrialization has made a small beginning at some of the rail centers and the former illiteracy of the population is disappearing. Though pastoral nomadism is becoming relatively less important among the Kirghiz, it has not disappeared completely, nor is it probable that it will within the near future, in view of environmental conditions in this part of the world.

Pastoral Nomadism in the United States. Though there are no nomadic herders who shift their livestock for great distances with the changing seasons in the United States, the Dinéh, "The People," or the Navajo Indians of our Southwest, move for more limited distances with their flocks and herds, which afford the major basis for support. Their homeland, economic activities, and ways of life will, therefore, be described to illustrate those of a semimigratory pastoral population.

The Navajos: The People and Their Country. The Navajos, more than 60,000 in number, are not only the most numerous of the full-blooded Indian population groups, but the 25,000 square miles of territory they occupy, about 62 per cent in Arizona and the balance in New Mexico, con-

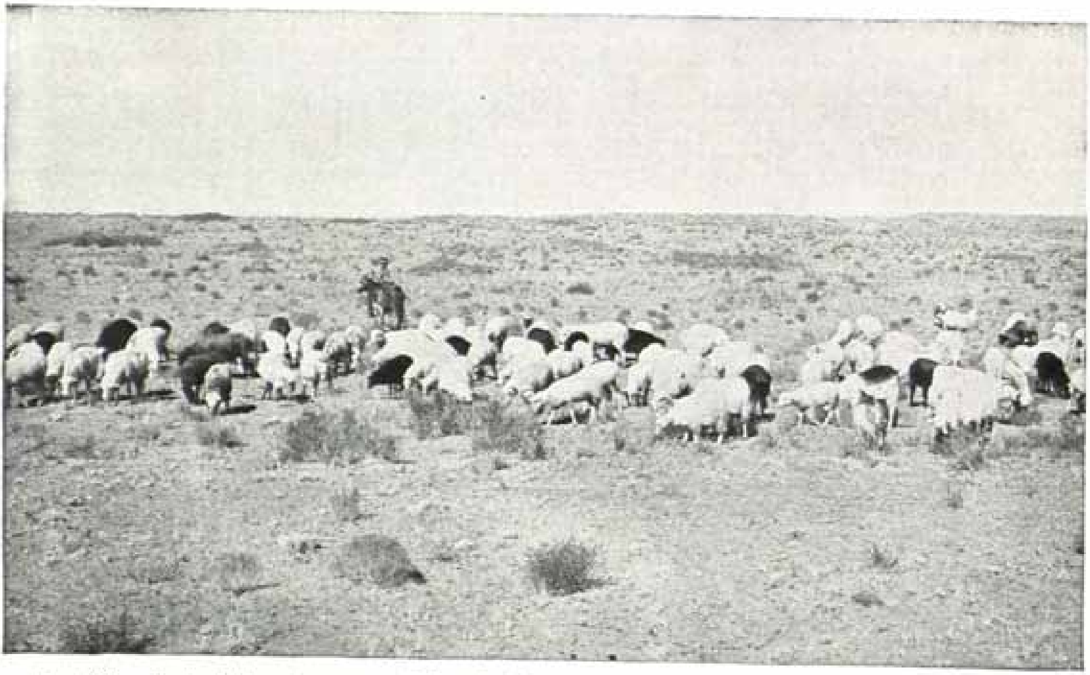

FIG. 274. Typical Navajo range with band of sheep and goats, and eight-year-old boy herder. Under intensive grazing, the grass cover has been largely destroyed and replaced by snake weed and Russian thistle. (Courtesy of the U. S. Soil Conservation Service.)

stitute the largest single continuous area remaining in Indian occupation in the United States.

The Navajo country, difficult of access, does not tempt preemption by whites, for it is not crossed by rail lines and by only a few roads, mostly poor and many only trails, so that most travel must be on horseback. Moreover, elevation is considerable, in few places less than 4000 feet; generally it is a mile or more, with the maximum of 10,419 feet reached by Navajo Mountain. These elevations are sufficient to affect climate appreciably. Thus, though the lower areas are hot in summer, with mild winters, summers are cool and winters are cold on the plateaus, with the daily range of temperature great everywhere at all seasons. Rainfall is light, in few places as much as 10 inches; in the western part of the area it is often 5 inches or less, for this is one of the driest parts of the United States.

The Navajo country is underlain by flat-lying or slightly tilted rocks, cut by canyons and surmounted by mesas. These afford the characteristic features of the angular topography of this arid region of dry stream beds, accumulations of coarse alluvium, sand dunes, and wind-eroded surfaces. Still in the youthful stage of dissection, it is a land of striking colors and magnificent scenery, but a poor land, because of the climate which is responsible for the land forms. This may explain in considerable part why an Indian population still remains in undisturbed possession.

The small amount of rainfall is reflected in the character of the native vegetation. At the lower levels in the west, where precipitation is very light, there is a desert flora of cacti, yucca, and tuft grasses; above 5000 feet, sagebrush, rabbit brush, and greasewood cover the salt and alkaline flats and border the drainage channels. With increase of elevation and rainfall, juniper appears at 6000 feet; slightly higher, piñon; and above 7000 feet, yellow pine, most important in the better watered eastern portion of Navajo Land. Cacti, sagebrush, and timber may not suggest grazing, but the stand is far from solid, and grama grass in the openings affords pasture after the rains, even in the desert west. Further, the sagebrush also furnishes food for livestock.

Migrations of the Navajos. Navajo migrations, except occasional movement for social reasons, are enforced by a local economy imposed by

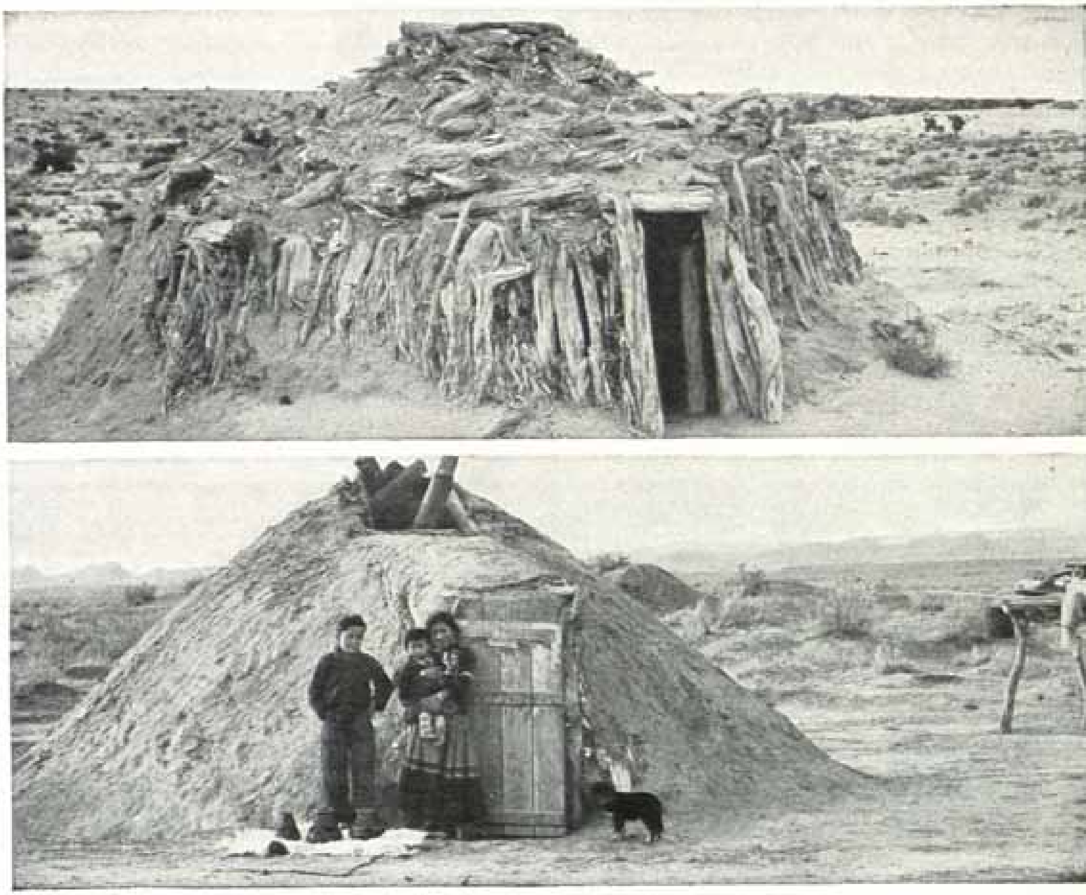

FIG. 273. *Top:* Abandoned winter hogan, showing the framework from which the cover of earth has been removed, Dinnahotso, Arizona.
Bottom: Occupied winter hogan, Dinnahotso, Arizona, with Comb Ridge in the background. (Courtesy of the U. S. Soil Conservation Service.)

climatic limitations: largely seasonal distribution of rainfall, with temperatures of secondary importance. Though water supply is most important in controlling migration, especially in the drier western portion of the Navajo country, in practice, movements of the people of any locality are complex and based on a variety of causes. Some, for example, may be to river flats to save the pastures of the mesas, 15 to 20 miles away, for winter use; some because it is easier to move than to haul fuel; still others may be motivated, at least in part, by social reasons. These migrations vary from a few to as many as 60 miles. The more extensive are to pastures in the mountains and on the high plateaus in summer and back to the lowlands in winter, where grass, springing up after the summer rains, affords food for the animals. Further, the highlands are cool in summer; the lowlands more pleasant in winter, as well as generally free from snow cover. Thus even the more important of the movements, those from summer to winter pastures, are related to more than one factor. These migrations are important in Navajo life since they affect the customs, the housing, the diet, and the material indications of progress.

Navajo Settlements, Houses, and Water Supply. The Navajos still cling to the "hohrahns" or hogans, which are grouped, but do not form villages, properly speaking. The temporary summer hogan is almost anything which will afford shelter, sometimes only a frame covered with

brush. That of winter, generally erected under sheltering cliffs at the base of a mesa which affords shelter and easy access to fuel and water, is more substantial and permanent in location, but variable in form and construction. Both have floors of dirt. Those which are roughly conical in shape have a supporting frame of five poles with forked ends, which meet at the peak of the shelter. This framework is interwoven with juniper or some substitute, covered with bark or brush, and then with earth. Another type, made of logs laid in a circle and plastered with mud, is dome-shaped. Still others are rectangular log structures with gable roofs, and some have side-walls of stone. The exact type varies with the site, the amount of timber available, the length of time the structure is to be occupied, and the wealth of the occupant. Therefore different types are common, even in the same locality. The only characteristic common to all is the location of doors on the east side, to greet the sun, the chief god of the Navajos.

The hogan is not a good indicator of the wealth of its occupant, since the migratory life led is not conducive to elaborate construction, which is still further discouraged by superstition, for a death in any household causes abandonment of the hogan. Furnishings are meager and limited to

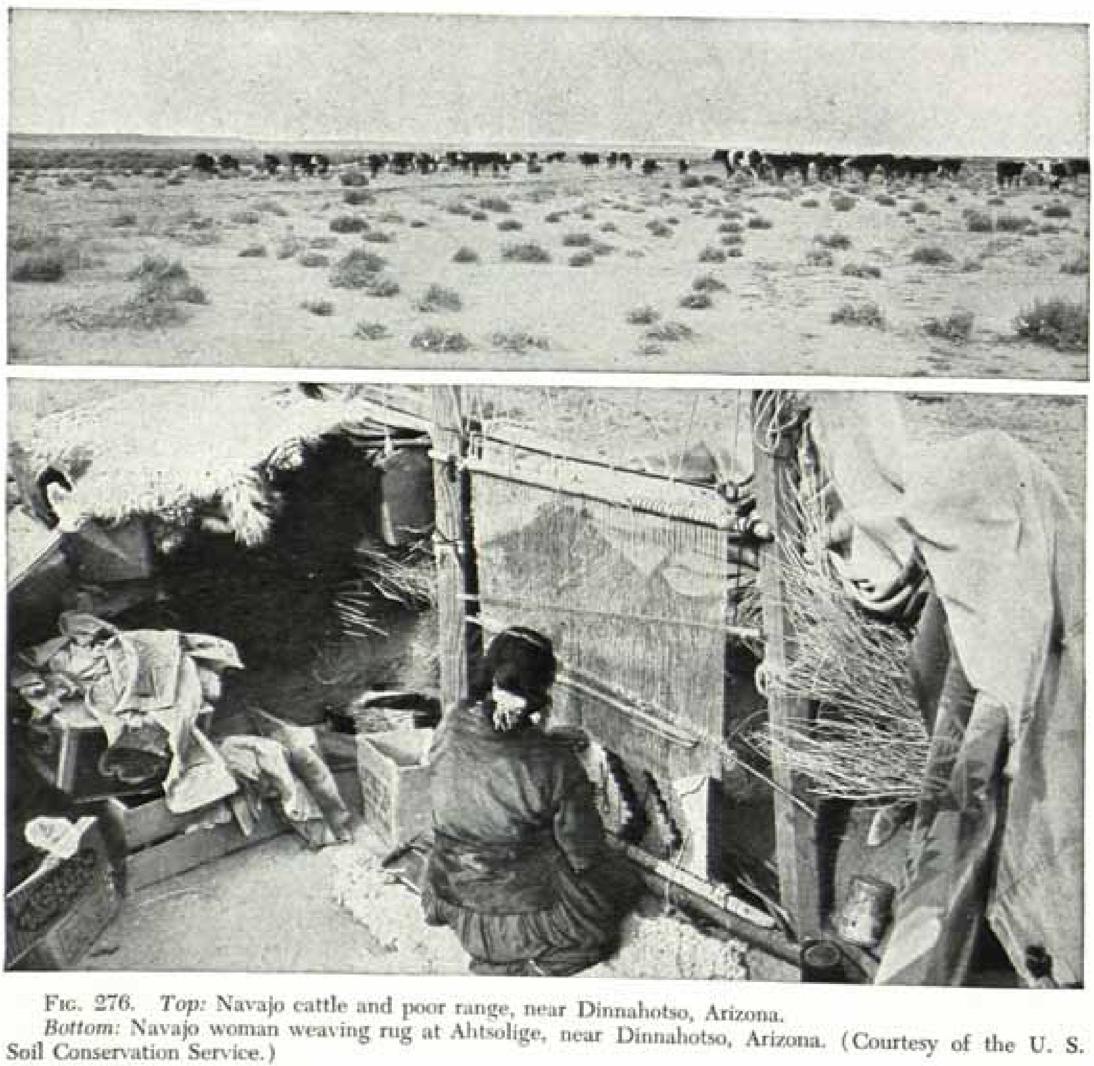

Fig. 276. *Top:* Navajo cattle and poor range, near Dinnahotso, Arizona.
Bottom: Navajo woman weaving rug at Ahtsolige, near Dinnahotso, Arizona. (Courtesy of the U. S. Soil Conservation Service.)

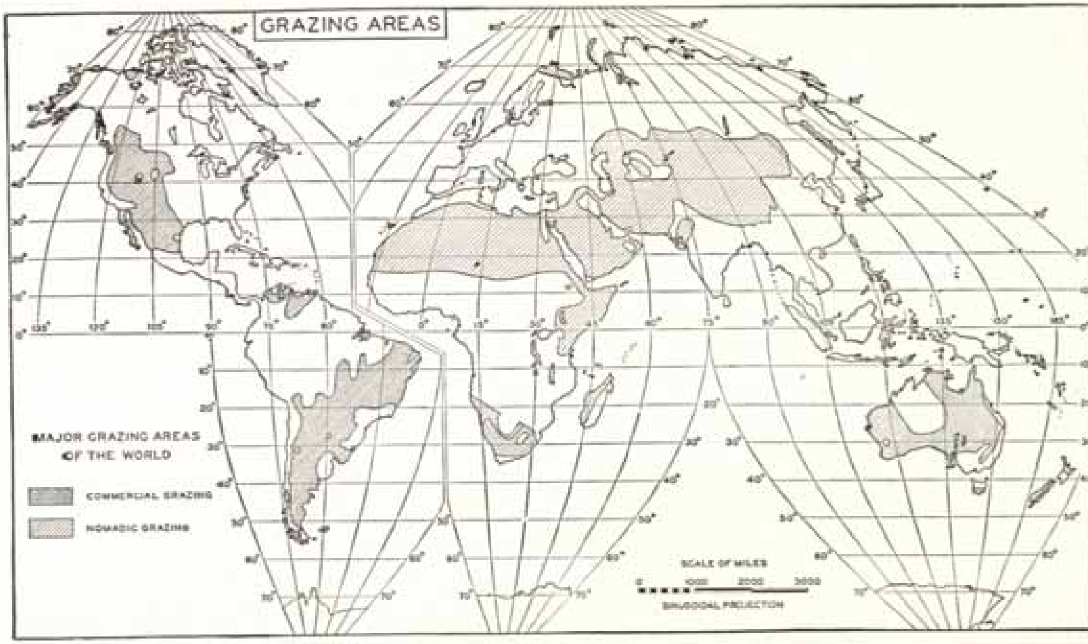

Fig. 277. The nomadic and commercial grazing areas of the world. Boundaries as shown are only approximations and highly generalized, since it is impossible to secure accurate data for many areas and, even though this were possible, detail could not be shown effectively on such a small map.

bare necessities, for accumulation of many possessions is impossible in the limited quarters and with the migratory type of existence led. Water for both domestic use and for the animals is secured from springs which issue at the base of the mesas.

Population Density and Economic Activities. Though the population density of the Navajo country is slightly less than two persons to the square mile, considering the present economic activities which serve as the basis for support it is already overpopulated, evidenced by the necessity for relief in 1947-48. The most important of these activities is grazing, under which use the range has been depleted and its carrying power reduced greatly by running too many head of livestock. In all, these number approximately 850,000 sheep and goats, 20,000 cattle, and 30,000 horses. Far too many horses are owned, as many as 300 to 400 by single families, for, except as they afford transportation and some meat, they are of very little value, yet one horse requires as much forage as eight sheep, and as much water as nine. In addition to those who depend on grazing for support, others engage in agriculture on summer locations determined primarily by the possibility of irrigation. Crops grown include alfalfa, corn, squash, and potatoes. Still others engage in weaving, using local wool and native mineral and plant dyes in production of the well-known Navajo blankets, the sale of which brings in important supplementary income. From these various sources, family incomes range from \$300 to \$2500 or more per year, though there are few families of great wealth. Originally, the Navajos were primitive hunting and seed-gathering nomads who habitually raided and looted the settled tribes; not until after contact with the Spaniards did they acquire livestock; agriculture is of still more recent origin. Today, however, supported by the activities of grazing, agriculture, and weaving, the last done by the women, the Navajos are not "vanishing Americans" but are and will continue to exist as an "outpost of Indian culture" in their desert environment for an indefinite period.

Grazing: Nomadic and Commercial. Both nomadic herding and commercial grazing are most important on the grasslands of plains and plateaus, regions with relatively flat land surfaces, but they differ from one another in the following fundamental particulars: (1) the type of area

where each is carried on; (2) the practices followed in grazing and feeding; and (3) the objectives attained.

Nomadic grazing is confined to deserts and their margins: areas where the vegetation cover is not continuous, pasturage is scanty, of poor quality, and soon exhausted under use. This necessitates much movement of flocks and herds, both daily and seasonal, and a migratory type of life for the herders. By contrast, commercial grazing, though normally an occupation of regions with light and marked seasonal distribution of rainfall, is an important economic activity only where precipitation is sufficient to support an essentially continuous vegetation cover, and permit permanent occupation of definite areas, with restricted movement of animals. Thus, whereas nomadic herding is an occupation of the desert and its margins, commercial grazing is commonly one of areas marginal to better watered regions devoted to agriculture, with its frontiers overlapping those of nomadic herding on the semiarid and desert border, those of agriculture on the wetter margin. In the tropics, the overlap on the wetter margin may be with areas in forest, where primitive, migratory agriculture is the common practice; in intermediate latitudes, with areas in continuous or essentially continuous cultivation, interrupted only by fallow fields, occasional woodlots, farmsteads, and other features of the cultural landscape.

The methods of nomadic herding and commercial grazing also differ. The nomadic herder depends entirely on natural pasturage. With its exhaustion, or with seasonal shortage, he moves his flocks and herds, always over range he does not own, except as custom, established by long use, may give him nominal claim to the land. In commercial grazing, on the contrary, there is no such continuous shift of pasturage and animals feed on a limited range, usually owned or leased, and often fenced. To supplement the pasturage afforded by natural growths, hay, both wild and cultivated, may be cut and stored, or other crops may be grown, often with irrigation, to afford dry season or winter feed for the animals. Often, indeed, alfalfa or other fodder, grown in near-by agricultural areas, may be purchased and fed. Thus the economic activities of commercial grazing and agricultural areas are often complementary.

Though both nomadic herding and commercial grazing serve to support populations, their objectives differ fundamentally. The pastoral nomad grazes flocks and herds with a view to attaining essential self-sufficiency, with never more than a small amount of exchange of a limited surplus for the products of other areas. With such a method of life, standards of living are never high, for only the bare necessities are assured; sometimes existence is even precarious. Cities and towns which serve his needs are therefore small and few in number, since they serve only small populations with limited wants, small surplus production, and thus restricted means for satisfying even the most fundamental needs. Commercial grazing, on the other hand, involves specialized production of animal products in which the objective is primarily the accumulation of a surplus to exchange for a great variety of articles impossible of procurement in the area where the flocks and herds are grazed. Commercial grazing, then, may permit a high standard of living, fully equal to that made possible by other economic activities. Therefore cities which meet the needs of such populations, though often widely spaced, may be of considerable size.

Tropical Grasslands and Commercial Grazing. The better watered tropical grasslands are commonly known as "savannas." Such areas are intermediate in location between regions of dense tropical forest and the deserts which border their drier margins. They are commonly laced with forest, with scattered trees elsewhere, the number varying with the amount of precipitation. All savanna grasslands have a marked seasonal periodicity of precipitation. During the short, rainy summer season, precipitation may be very heavy, but during the much longer dry season it is always light. Often no rain falls for many weeks at this time of the year. These are conditions which permit the growth of grass but do not favor the development of forests, those which exist being drought resistant in character and confined to the better watered localities. Elsewhere, the trees are scattered, and everywhere they tend to lose their leaves during the dry season.

The grass of the savanna is tall, often higher than a man's head and sometimes even reaches the lower branches of the small trees. (See Fig. 242.) Seldom does it cover the ground to form a sod; rather it grows in clumps which do not unite to form a continuous cover. After the rains,

the new green shoots are palatable to animals, but later in the season the tall, rank growth becomes hard and tough and, when it dries out, even more poorly adapted for use as feed for domestic animals.

In view of these characteristics of the native vegetation, the pasturage is rather poor except for a limited period of time immediately after the rains. Then the cattle feed on the green shoots which appear as the ground dries out. Even at this time of the year, conditions are far from ideal, for the cattle must travel across wet and even flooded areas to reach the pasture, which is often fouled by aquatic growths. Insect pests, disease among both men and the animals, labor shortages, distance from market, and inadequate transportation facilities are also handicaps. Nevertheless, commercial grazing of cattle is an important economic activity in the Llanos region of northern South America, the Campos region of southern Brazil, the Sudan of northern Africa, and the savanna grasslands of the southern part of the same continent.

Sometimes the pastoral activities of the savannas, though not definitely nomadic in character like those of deserts and their margins, are organized primarily on a subsistence rather than a commercial basis, particularly among native populations of relatively low development. For this reason, such activities of the tropical grasslands are often of a type transitional between that of the desert margins and those of the better steppes or grasslands of higher altitudes. This is the condition in much of the savanna grassland of both South America and Africa.

Use of the Savannas of South America for Grazing. Grazing of cattle is the dominant economic activity on the grasslands, mostly below 1000 feet in elevation, which border the Orinoco River and its tributaries. In this area of approximately 100,000 square miles lying to the west of the Guiana Highlands of northern South America, the lower land is wet or flooded from April to October, during and after the 30 to 35 inches of summer rainfall, and grazing is restricted to exposed hummocks so that pasturage is limited. During the dry season, from November to March inclusive, the grasses are hard and dry and animals may die from lack of water. Further, the cattle are subject to attack by insect pests and disease so that it is difficult to produce high-grade beef. Again, they must be driven 100 to 400 miles to market. Therefore they arrive in poor condition and must be fed before shipment or slaughter. Also, labor is scarce and political conditions are unsettled. Thus, though cattle are the chief source of wealth in the Llanos region, and grazing is the principal economic activity of its sparse population, which seldom rises to as many as 10 and generally falls to about 2 persons to the square mile, surplus production is relatively small and export of live animals, meat, and hides is limited. That the industry is not prosperous is indicated by the fact that there are only about half as many cattle grazed today as there were 75 years ago, and probably even fewer than during colonial times.

In the Campos region, an area adjacent to the Upper Paraguay River and including the bordering uplands of southern Goyaz and Matto Grosso in Brazil, conditions are similar to those of the Llanos region. During the rainy months of December, January, and February, nearly 30 inches of water fall; during June, July, and August, the total precipitation may be less than 1 inch. Since grazing is confined almost entirely to flat, low-lying lands, because their proximity to rivers affords the possibility of water transportation, the pastures are either very wet or flooded during the rains. During the dry season, the grass is dry and harsh and pasturage becomes so poor it is often purposely fired to expose smaller succulent growths, to assure a fresh crop of green shoots for the cattle. Further, ticks and flies harass the animals and transmit disease. Herds are large but the quality of the livestock is poor. In attempts to improve it, zebu or humped cattle have been introduced, but there are no fences so that controlled breeding is difficult. In addition, the meat from the crossbreeds is poor. Here, as in the Llanos, the grazing industry supplies only a relatively small surplus, much of which is marketed as jerked or dried beef. In spite of these handicaps, the grazing of 5,000,000 or more head of cattle affords the principal basis for support of the limited population of the area.

Use of the Savannas of Africa for Grazing. In the Sudan, to the north of the equator in Africa, the savanna or tropical grassland represents a zone of transition between the dense forests of the Congo basin and the desert vegetation of the Sahara. This change is not sudden but gradual. First, the grassland is broken by ribbons of forest, where streams or ground water

permit tree growth of some type; then rolling grassy plains, scattered with trees and interrupted by occasional ridges, occur; and, finally, the desert, all at moderate elevations. In this area, cattle are the principal support of a large fraction of the dense native population. But, though the Fulani herdsmen of northern Nigeria and those of other tribes depend on their herds, surplus production is limited.

South of the equator, in the Union of South Africa, surpluses are larger, for there the grazing industry is in part carried on by white populations, employing native labor. In the Great Karroo, the Upper Karroo to its north, the Little Karroo to its south, and in the High Veldt, where precipitation ranges from 5 to 15 inches, both cattle and sheep are grazed, with cattle most important in the High Veldt. Except there, the sheep, merinos, are raised for wool; in the High Veldt, for both meat and wool; cattle, for meat and dairy products.

In the terraced foreland of the Cape Province, in Natal, and in the Basuto highlands, where precipitations range from 20 to 30 inches, the native Bantu populations depend on cattle and, to a lesser extent, on sheep as their basis for support, though agricultural use of the land might seem possible, considering the amount of rainfall. Despite the large number of cattle grazed, however, there is little or no surplus production, the only animal product which enters into trade in any important quantity being wool from the 2,000,000 sheep of the Basuto highlands.

Among these Kaffir pastoral populations, dwellings are simple and the plan of the kraal or village reflects the importance of livestock. Among the Zulus, of whom there are approximately 230,000, inhabiting well-watered grassy plateaus of 2000 to 4000 feet elevation, which lie roughly between 27° and 29° South latitude and 31° and 33° East longitude, for example, the kraals are circular enclosures, with a ring-shaped fence or stock corral at their centers. This is surrounded by the conical huts of the inhabitants, and these, in turn, by an outer enclosure or barricade.

In addition to grazing flocks and herds, these populations practice limited agriculture, raising mealies or maize, Kaffir corn or millet, yams, tobacco, and various vegetables. Milk, never used fresh, and mealies are the staple foods. Cattle are likewise the chief form of wealth as well as an important basis for support, prices being commonly reckoned in cows. Thus the price of a wife varies from 10 to 20, and occasionally to as many as 80 cows, in the case of an outstanding belle.

The sedentary native populations of the savannas, though dependent primarily on grazing for support, with agriculture of secondary importance, produce but little in the way of surpluses for exchange, and the same is true for more advanced, sometimes white populations of similar areas. Again, it cannot be expected that production will increase greatly or that white occupation of such grasslands will expand materially, at least in Africa, for the savannas of that continent already support dense native populations. Possibly the distant future may witness an increase in the importance of commercial grazing and the production of increased surpluses by the savannas of the tropics, but if such proves to be the case there is little to indicate its probability today and much to encourage the belief that they will always remain at best only second-rate areas for commercial grazing.

Steppe Grasslands and Their Use. Steppes are grassy plains and low plateaus of intermediate latitudes, or even of the margins of the tropics, but typically developed in areas with cold, dry winters, hot summers, and from 12 to 20 inches of precipitation, the exact amount varying with latitude and the rate of evaporation. On their better watered margins in the United States, they merge gradually along a fluctuating line with the tall grass prairies, where rainfall exceeds 20 inches and there is abundant soil moisture at depths of 2 feet or more, and a change in the soil type. On their drier borders everywhere, they grade imperceptibly into semidesert and desert grasslands, this boundary likewise being variable and marked by a change in soil type.

On the better watered eastern margin of the Great Plains, a typical steppe area in the United States, the short grama grass of the north and the buffalo grass of the south (see Fig. 244) give way to tall bluestem, needle grasses, and the numerous flowering plants of the prairie (see Fig. 243); on the drier western border, to clumps of grass and scattered desert shrubs such as sage, mesquite, creosote bush, and yuccas. (See Fig. 245). The boundary line to the east is roughly the 100th meridian; to the west, the steppe grass-

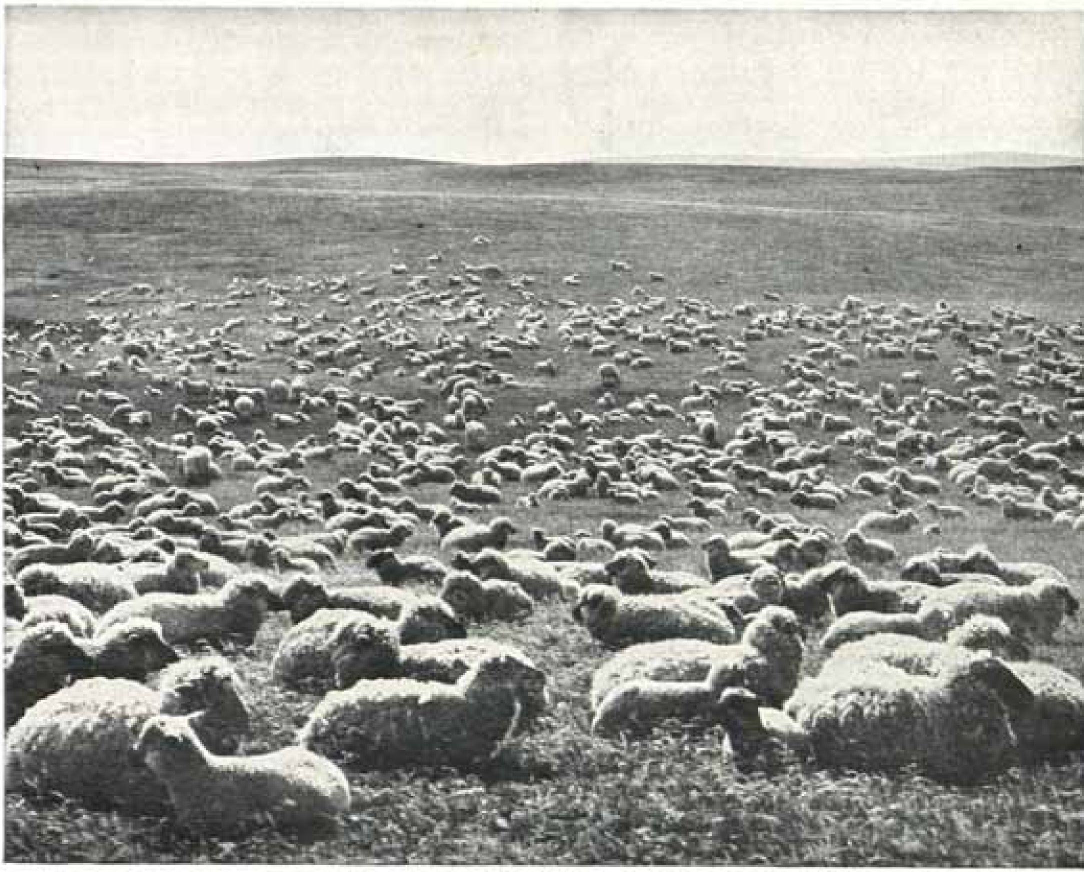

FIG. 278. Ranch and sheep near Calgary, Alberta, Canada. The high plains here have an elevation of about 3500 feet, a rainfall of 16 inches, bitterly cold winters, and hot summers. These conditions are satisfactory for the support of short grasses but not for agriculture, except with irrigation, hence most of the land is used for grazing. (Courtesy of the Canadian National Railways.)

lands extend to and into the foothills of the mountains and the deserts of the southwest.

In these steppe grasslands, the relatively small amount of precipitation is ample to support short grasses, some hard and some soft, with thorny, shrubby growths and cacti dominant in the drier areas. Not only is the rainfall limited, but the amount received in any one year is subject to great departure from the average so that, where agriculture is attempted, periods of drought, sometimes of several years duration, often wipe out all gains of the wetter years, when rainfall is sufficient to permit production of bumper crops. Attempts at dry farming have, therefore, been generally unremunerative, except in the more favored portions of the steppe grasslands. Because of the limitations climate imposes, these grasslands should in general be used for grazing, for, even under irrigation, agriculture is often unprofitable.

Under such use, returns are generally satisfactory, except as overgrazing levies such a toll on the native grasses that they are destroyed in part and the carrying power of the range is decreased to an extent that profits disappear. When this occurs, both wind and water cooperate to decrease still farther the value of the pasturage, with initiation of erosion. To reestablish the grasses after their destruction by overgrazing and erosion is difficult in such dry areas where, even under the most favorable conditions, vegetation must wage a continuous and strenuous fight for existence.

In these steppe areas, the grazing industry

may be either nomadic or commercial in character, dependent in considerable part on the stage of development of the population. Among less advanced groups it is often nomadic, with self-sufficiency the major objective and standards of living low; among more advanced populations, commercial in type with the objective production of a surplus for exchange and standards of living high. Everywhere, commercial grazing today presses on the limits of steppe grasslands given over to nomadic herding, with the result that the latter has retreated to the less accessible and desirable areas. In either the nomadic or commercial grazing of steppe areas, both sheep and cattle are raised; sheep in the drier portions; cattle where the precipitation is heavier and pasturage is better.

The Grazing of Sheep. The grazing of sheep is one of the more important as well as one of the oldest of man's uses of the land. Supposed to have originated in the dry plateaus of Eurasia, it has spread into similar areas in Australasia, Africa, and both Americas. Such use of the land enables effective employment of many and diverse areas not valuable for other purposes, particularly those of the drier steppes, because sheep can feed on very short grasses and poor pasturage; their fleece protects them from cold; and they can go without water for days or even weeks if feeding on succulent food.

Grazing of sheep has always been an industry of the frontier, either temporary or permanent, giving way to more profitable uses of the land with the change in opportunity which accompanies development. This frontier character of sheep grazing results in part from the fact that sheep can be raised where other animals cannot subsist and in part because wool, next to cotton the most important of our natural textile fibers, can be handled at low cost and without spoilage in transit. The same is true for sheepskins. Thus the grazing of sheep to supply wool and skins is generally most important in the driest and most inaccessible of the areas used for raising sheep. The third product, meat, is, on the contrary, secured from those areas where transportation conditions are better. Thus Australia, an area the size of continental United States, with 60 per cent of its land surface best adapted to raising sheep, specializes in merinos and wool production in the drier areas; where better watered, in raising sheep for mutton.

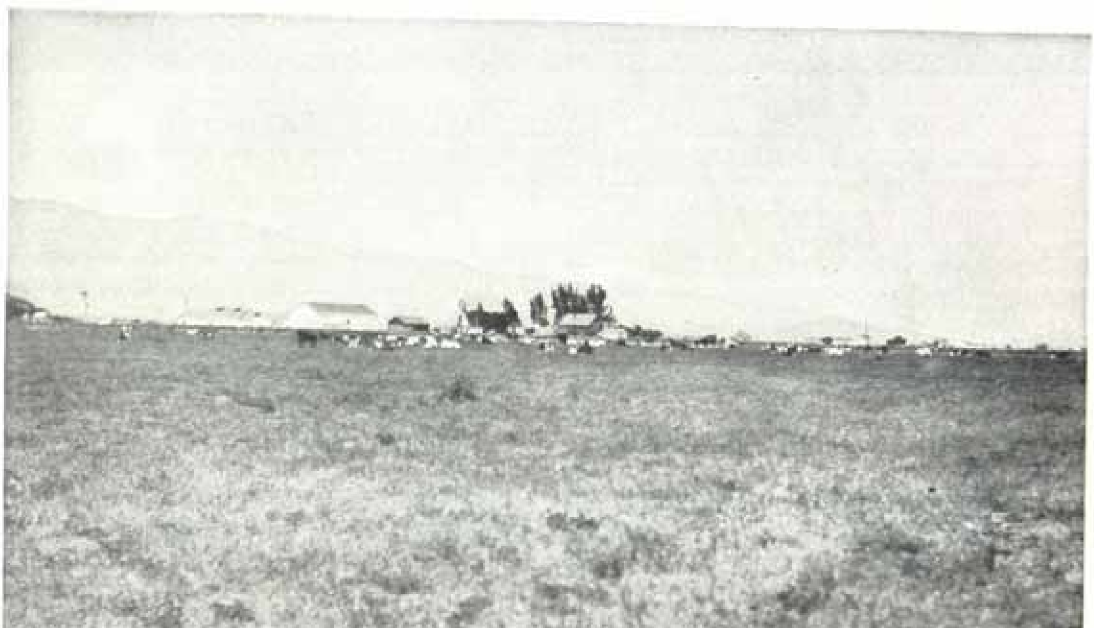

FIG. 279. A California cattle ranch in the Salinas Valley, about 30 miles south of Salinas. The cattle are grazed on the Coast Ranges in the background when winter rains make pasturage good. In this view, taken in July, they are feeding on alfalfa, raised with irrigation.

On our own western range, sheep were formerly grazed in large bands of from 2000 to 5000 on free and unfenced pasturage, under the care of herders, and often in competition with cattle. Today, with disappearance of the temporary frontier, some 20,000,000 head are grazed on owned or leased land, with a total capitalization which may be as high as $14 per animal. With this practice, winter feeding is necessary, except in the south where the range is relatively free from snow throughout the year. Even there, supplementary feeding may be practiced when natural pasturage is inadequate. This affords effective use for local crops, grown under irrigation. Despite feeding, losses resulting from straying, eating poisonous plants on the overgrazed range, depredations by predatory animals, and attacks by parasites, average from 7 to 10 per cent each year. Many of the range sheep are raised primarily for mutton. These are shipped east to better watered areas to be fed for the market. The sheep products, wool, skins, and meat, are of great importance to man, particularly the wool, which is used for making clothing, blankets, carpets and other articles. In the United States, we do not produce our annual requirecent of 5 pounds per person, hence we must import large amounts from other parts of the world. Fortunately, wool is a substance which is not destroyed completely in use but may be reclaimed and used several times. Therefore annual production does not have to equal consumption. Further, increased use of new fibers, many of synthetic origin, has caused a decrease in the demand for wool, as the area devoted to the pasturage of wool sheep and the production of wool has diminished. This shrinkage of the area devoted to such use is often desirable, for it indicates that man, despite his occasional and too-frequent lapses, does make some progress in effective use of environmental opportunity.

The Grazing of Cattle. The grazing of cattle is an important industry, not only on the tropical savannas where it is an economic activity of many self-sufficient native populations, and of some importance as a source of surpluses, but in areas of steppe grassland as well, where commercial production dominates. Though we do not know exactly where the grazing of cattle originated, we are certain that it had its beginnings in the better watered grasslands of Eurasia, possibly in southern Asia. From this center it spread to other parts of the Old World, perhaps as an accompaniment of the great movements of population of earlier times and, with discovery of the Americas, to the New World.

At the present time, the most important areas devoted to commercial cattle grazing are the better watered steppe grasslands, particularly those of the Western Hemisphere. Much of the better watered Great Plains region of the United States, and adjacent areas across the International Boundary in Canada, for example, are in such use today. There, the cattle are grazed during the summer on fenced range and fed during the winter or when pasturage is poor, much of the hay used for supplementary feeding being grown under irrigation, either on the individual ranches or in adjacent irrigated agricultural areas. Grazed on the range, these cattle are commonly shipped east for feeding before slaughtering. Thus they serve as a means for marketing agricultural products in the form of finished beef, when meat prices ensure a profit.

A second commercial grazing area of some importance in the United States is located in central and southern California, where a combination of light rainfall and a winter maximum of precipitation ensures grass rather than tree growth, and limitation of agricultural use of the land, except under irrigation. Here, winter pasturage, good because of winter rains and no snow cover on the low hills of the Coast Ranges, is supplemented by irrigated pastures of alfalfa or some other fodder crop during the summer.

A somewhat similar grazing industry is found in other parts of the world with the same type of climate. Thus there are large numbers of sheep raised for wool in Spain, and other Mediterranean countries have comparable grazing industries, but principally the raising of sheep and goats rather than cattle. Reference to the Old Testament will show that this industry has long flourished around the east end of the Mediterranean, for in Biblical times the Hebrews were largely a pastoral people. This is indicated not only by the accounts of flocks, herds, and pastures, but by the numerous figures of speech in the Old Testament which indicate the existence and importance of the pastoral pursuits.

Grazing of animals, so long important as an economic activity of man, has, with the passage of time, declined markedly in relative importance, today being restricted to those less promis-

ing areas where it has not been supplanted by other more profitable economic activities. Further shrinkage of the grazing area will probably be inconsiderable, nothing like that experienced in the past, for the temporary frontier of agriculture has largely disappeared and other activities can no longer challenge the cattle and sheep successfully in competition for the areas they use; in fact, grazing may even recapture certain areas now in unwise agricultural use.

QUESTIONS AND EXERCISES

1. Upon what do pastoral nomads depend for support? How large are the numbers of such populations? Are they increasing or decreasing? What fraction of the earth's land surface do they occupy? Describe their migrations and state their cause.
2. Why are material possessions limited among pastoral nomads? Why did such populations formerly raid their more fortunate neighbors? Did such incursions ever assume serious proportions? Why do they no longer occur to any important extent?
3. Locate the homeland of the Kirghiz. How does its location favor pastoral nomadism as a way of life? What is the area and population of the Kirghiz S.S.R.?
4. Describe the topography, drainage pattern, climate, and native vegetation of the homeland of the Kirghiz. In what respects do they favor a nomadic pastoral life?
5. What are the domestic animals of the Kirghiz? What is the yak? For what is it used by the Kirghiz? For what are their other domestic animals used? What is meant by "transhumance"?
6. Describe the migration of the Kirghiz from winter to summer pastures? Is this a simple movement? Why?
7. What tasks do the Kirghiz men perform? The women? How is the Kirghiz shelter or yurt constructed? How is it adapted to the life the Kirghiz live?
8. Describe the material possessions, the clothing, and the food supply of the Kirghiz.
9. To what extent has commerce developed among the Kirghiz? What is the nature of the trade?
10. What changes are occurring in the older ways of life of the Kirghiz? What has produced this change?
11. Describe the homeland of the Navajos, their migrations, and their habits of life. What economic activities serve as the basis for their support?
12. Describe the hogans and the settlements of the Navajos. What are the causes of their migrations?
13. Contrast nomadic herding and commercial grazing as to locations where carried on, methods followed, and objectives.
14. What are savannas? Describe their vegetation. Why is pasturage poor much of the time? Describe the use of the savannas of South America. Of Africa.
15. What are the handicaps from which the grazing industry suffers in savanna areas? Why is commercial production of animal products small in such areas?
16. What is steppe grassland? Where and under what climatic conditions does it develop? Into what other areas do the steppes merge on either margin?
17. Discuss the grazing of sheep on steppe grasslands. Why is this always a frontier economic activity?
18. How has the sheep-grazing industry altered on our western range within recent years? What products of this industry enter into trade? From what types of area does each of the products come?
19. Why are the great commercial cattle-grazing areas steppe rather than savanna grasslands? Describe grazing practices on our western range.
20. How has the relative importance of the grazing industry altered during the past 200 years? Will grazing continue to retreat before the advance of agriculture as it has in the past and, if not, why?

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Chapter Thirty

PRIMITIVE AGRICULTURE

The Beginnings of Agriculture. The beginnings of agriculture are so lost in antiquity that its history is essentially that of man, subsequent to the time when his habits of life were clearly differentiated from those of the higher animals. These beginnings doubtless occurred when it was discovered, probably by germination of seed accidentally dropped near camps, under conditions favorable for growth, that certain wild plants could be propagated to advantage on plots of ground chosen for that purpose. This marked an important step along the path of progress of the human race, since domestication of plants eliminated the waste of effort involved in searching for the wild species which satisfy certain of man's needs; it obviated the necessity for frequent shifts of location to secure the yields afforded by nature; and it ensured both a better and more adequate supply of food. Then, more or less fixed settlements and sedentary habits of life became possible. Thereafter, it must have been but a relatively short time before discovery that, by selection of seed, plant varieties could be improved and greater productivity assured. From such simple beginnings, the centuries have witnessed the gradual evolution of our present-day crops, some resembling their wild ancestors but slightly, and our current agricultural practices.

Not all parts of the world have experienced the same amount of change from what must have been the earliest types of agriculture. Thus many less advanced populations still continue, more or less unmodified, the practices of much earlier periods, such as those described by Caesar for the Germanic tribes. For example, the Fang, a Bantu people of the Gabon, a division of French Equatorial Africa, still practice a migratory, exploitive type of agriculture, associated with other supplementary economic activities which afford part of their food supply and other necessities of life. This population group and their methods of obtaining a livelihood will be described as illustrative of the primitive agricultural and other practices of migratory, semiagricultural populations of tropical forests.

The Fang and Their Homeland. The Fang or Fans, whose name means "men," were formerly an inland people of the hilly plateau north of the Ogowe River and its affluents, but their migrations have today carried them to the south and west into the lower Ogowe Valley, so that they now occupy much of the Gabon, being neighbors of the Mpongwe or Pongos, a settled Bantu population established near Libreville; south of the Gabon, they have even reached the sea in several places. For purposes of this consideration, N'Djolé, in the middle Ogowe Valley, will be considered as centrally located with reference to their territory.

The surface and soils of the area occupied by the Fang vary considerably. In the extreme west, where the Ogowe River widens to over a mile, it flows through an alluvial plain with moderately productive clay soils. In this well-watered plain, where many water-filled depressions and lakes border the course of the main stream, conditions are relatively favorable for man. Somewhat farther upstream, however, where the edge of the African plateau begins a few miles above N'Djolé, the river narrows as it crosses north-south ridges which rise to elevations of from 500 to 800 feet. Here, valleys are narrow and steep sided; erosion is active; soils are hard, compact clays. Above N'Djolé, in the area drained by the tributaries of the Ogowe, hilly and mountainous tracts are interspersed with alluvial deposits of considerable elevation. In the extreme east, the soils are impervious, of low humus content, and poor,

but except along the river courses the land surface is somewhat more level.

Rainfall is everywhere abundant, except in the extreme northeast, averaging about 60, but variable from 50 to more than 70 inches, both from place to place and from year to year in a definite locality. This amount of precipitation is not uniformly distributed, for there are two rainy seasons, with two intervening dry periods each year. The first of the two rainy seasons begins about the middle of March and lasts through May; the second, in early October, continuing until late in December. Rains are torrential in character, as much as 7 inches of water sometimes falling in a 24-hour period. The seasons of heavy rainfall are times of flood in the Ogowe River and its tributaries, the main stream, which has an effective channel depth of not more than 3 feet during low-water stages, then rising as much as 20 feet or more above low-water levels and flooding extensive tracts of land.

Throughout the area occupied by the Fang, temperatures are continuously moderate to high, varying from about 65° F. during the dry months of July and August to a maximum of 85° F. in the shade in February and March. The most comfortable time of the year is the second and longer dry season, which lasts from June to late September. This is the favorite season of both natives and whites, for the weather is then agreeable, forest trails are at their best, and food is abundant.

Except in the extreme northeast, forest covers the entire area. There, it is restricted to narrow belts along stream courses, the interstream areas being covered with grassy growths and scattered, stunted trees, much as are the better watered margins of the Sahara. Due to periodicity of the rainfall, plant growth is not uniform throughout the year. During the dry season, from mid-June to mid-September, vegetative growth is checked and some of the trees shed their leaves; with beginning of the rains in early October, vegetation revives, to flower and fruit toward the close of the wet season.

Agriculture and the Animal Industries among the Fang. The agriculture of the Fang is exploitive in type, not based on prolonged cropping of any tract, but upon clearing, temporary use, and abandonment of fields when decrease in their yields becomes serious. Such use of land is obviously impossible except in a sparsely populated region, and is common only with primitive types of agricultural practice.

The Fang regulate their activities according to the seasonal distribution of precipitation. Clearing of new land for the larger plantings usually begins in late January and early February, when it is relatively dry. First the underbush is cut by use of the machete, a large, heavy, imported knife, which has displaced the "fa" or knife of native manufacture during late years. This work is done by both sexes. After removal of the underbrush, the men attack the trees, except for a few forest giants and some of those which bear edible fruits. All this work is done with difficulty, for the heat is trying, some of the trees are large, and the tools used primitive and poorly adapted for removal of the dense forest cover. The work of clearing must be completed by the last of February, for the rains are due shortly thereafter and the brush still remains to be burned before their coming. This is done early in March and in the soil, fertilized by the humus of the forest and the ashes of the burning, plantains or bananas, manioc, yams, gourds, and other crops are planted, which, taking advantage of the rains of late March and the high temperatures, grow rapidly and serve to provide a food supply. If the rains fail, crop yields are reduced; if they come too soon, planting is prevented and the clearing cannot be used. However, disastrous famine is unknown and no one dies of hunger, for many of the native crops are hardy and the plantain fruits throughout the year. Hence there is little or no storage of food except of limited amounts of dried meat. The only precaution necessary to ensure against food shortage is to make certain that new plantings come into production with exhaustion of those which have been in use for two or three years, by the end of which time yields will have decreased seriously. With such a system of agriculture, producing areas shift rapidly and continually and, with their shift, settlements too alter their location.

In addition to the clearing, work is also necessary in June, when weeds threaten to choke out the plantings. Otherwise, the larger fields, located at some distance from the villages, need little or no attention, except that they must be watched to protect them from marauders and destruction by wart hogs and other animals. Near the settlements, the Fang also cultivate small gardens in which vegetables such as groundnuts, cucum-

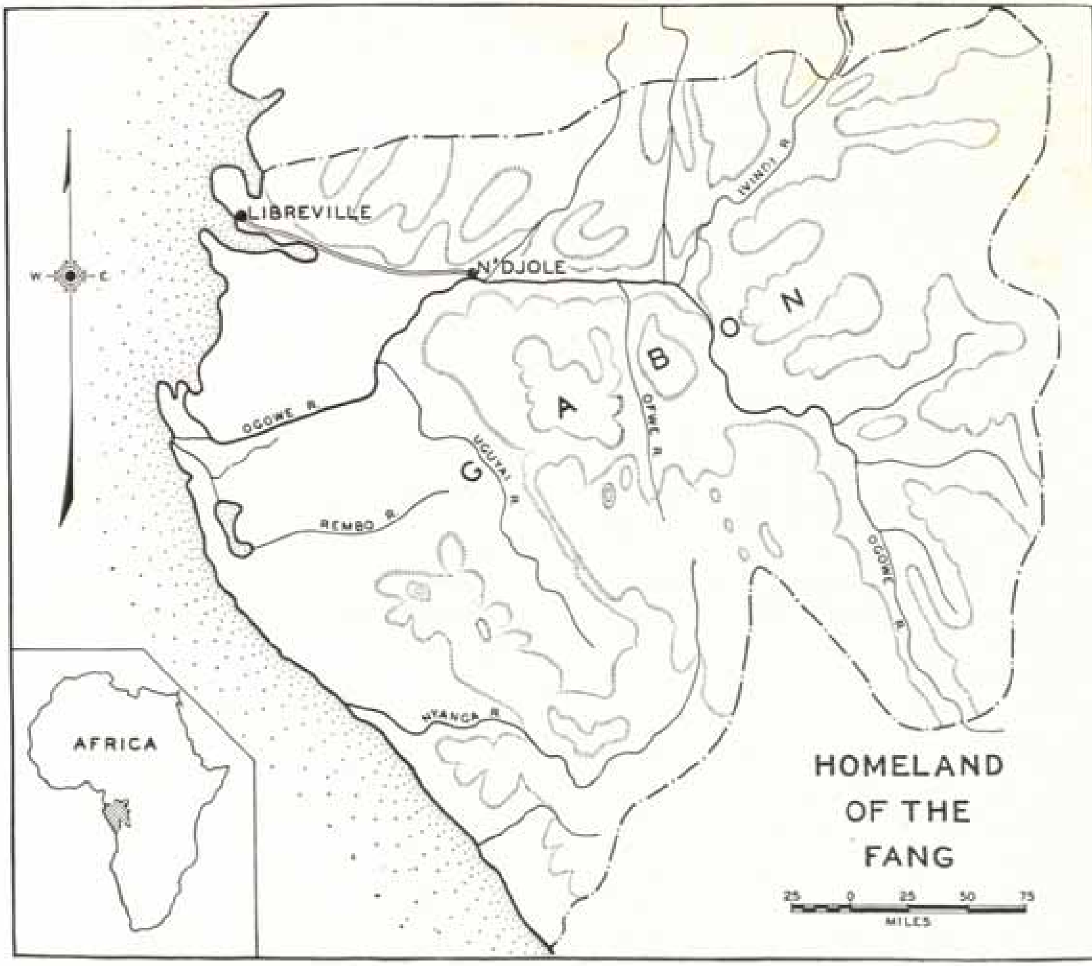

FIG. 280. The homeland of the Fang, a Bantu population of the forest area of equatorial Africa.

bers, tomatoes, and others are grown. These are cleared during August and planted early enough to take advantage of the October rains, their crops ripening in December, when rains diminish and days are sunny. In both the larger and smaller clearings, forest devastation and fire are preliminary to cultivation in these migratory agricultural activities.

The Fang have few domestic animals. Chickens, ducks, and a few sheep and kids, the latter reserved for the payment of debts, the purchase of wives, and for use as sacrifices, make up the complete list. Often the number of sheep and kids for an entire village will not exceed a dozen, an indication of the small importance of the animal industries.

Other Economic Activities of the Fang. The Fang secure part of their food supply by gathering edible forest fruits which ripen during the sunny days of the first of the year. Some of the fruit is eaten fresh; some is cooked, when, if properly cared for, it will keep for as long as two weeks. All the work of gathering and caring for these forest products is performed by the women; the men contribute only by building and protecting the temporary camps.

Fish and game also supplement the food supply afforded by the plantations and gardens. Fishing, important only during the longer dry season, when the water of ponds and lakes is low, begins in August and is especially important during the last six weeks prior to the first of October. Fish

are caught in nets, by poisoning the water, and by draining the pools in which they have taken refuge. Profitable fishing, however, is limited to those areas where the Ogowe river widens and pools are numerous on the flat, bordering alluvial plain; elsewhere, where the river current is swift over the rocky bottom, fish are few. Nevertheless, fishing is attempted even under these unfavorable conditions, for fish, plus the plant products of field and forest, are the major items of the diet of the Fang.

With such a scarcity of animal food, it is not surprising that the Fang hunt whenever and wherever opportunity offers. The best times are when the rivers flood and game is trapped on the higher ground; the best places are those far removed from the villages, for there game is more abundant. Thus the good hunting season is short, and the same is true of the duration of the hunting trips, which must be provisioned from village supplies. Few women accompany the hunters, only a sufficient number to do the cooking, provide wood, and smoke the meat. If good fortune attends, a few wart hogs, antelope, and other animals may be secured, the meat of which relieves the monotony of the normal food supply of the lucky hunters and their families.

Other economic activities, based on the forest resources, but important only since the coming of whites, include cutting of ebony, mahogany, and rosewood; collection of copal gum and wild rubber, now a vanished industry; and the hunting of elephants for their tusks. All of these highly exploitive economic activities destroy the basis for their existence and hence become of continually decreasing actual and relative importance.

Settlements of the Fang. The Fang villages are always located near streams and lakes, for these afford a supply of water for domestic uses, as well as an opportunity for fishing. Further, the Ogowe River and its tributaries are the major highways. N'Djolé, located on the main stream at the head of navigation for small river steamers, is the commercial center of the territory and a focus of attraction for Fang villages. Settlements are usually on the bank of a river or lake, but always on high ground not subject to inundation at times of flood.

The village plan is very simple: a single street bounded on either side by houses, without any open space between the individual structures. Protection is assured at the two open ends of the street by solidly built guardhouses, whose narrow entrances and numerous loopholes furnish a view of the road and river over which enemies may approach. In the larger villages, there may be as many as four additional guardhouses, located at intervals along the single street, to increase the security from attack provided by those which block its ends. These structures also serve as community halls, common eating places for the men, and for the reception of strangers.

Men and women live in separate rectangular huts with roofs of leaf thatch over a light support of poles; side walls are of bark, fastened by vines to the framework of posts and crosspieces which supports the roof. The construction material varies considerably, dependent on local supply. Thus, sometimes much wood is used; again, but little, where the trees do not furnish satisfactory material. Buildings are neither substantial nor large and little labor is required for their erection. Therefore, when a village is abandoned, no great loss is incurred.

Clothing, Other Material Possessions, and Weapons of the Fang. In common with other primitive populations of the warmer parts of the earth, the Fang wear little clothing, for it is unnecessary. A bark waistcloth is worn by the men; a plantain-leaf girdle plus a bustle of dried grass by the women. The chief may, in addition, wear a leopard skin around his shoulders. This completes the attire, except as it may be modified by contact with white traders and missionaries. Both sexes tattoo and paint the body and wear many ornaments.

The Fang are skillful workers in iron and even have a coinage of sorts called "bikei," small imitation axe heads, tied in bundles of ten, and used principally for purchasing wives. Household equipment, though limited, is more diverse and complete than that of migratory hunting populations of less favored areas. Weapons include muskets, spears, throwing knives, and ebony crossbows; bows and arrows are not used. In former times, the men carried shields in battle, but this is no longer true. Great importance attaches to these weapons, for the only occupations of the men are hunting, fishing, fighting, and limited participation in clearing the land for plantings and the establishment of camps and villages. Their characteristics of intelligence, ferocity, indifference to life, and the ease with which they take offense, make the Fang formid-

able opponents in warfare, feared by their neighbors, who therefore submit to preemption of their territory.

Migrations of the Fang. In addition to temporary migrations from the villages to gather wild fruit in the forest, and to hunting and fishing camps, the villages themselves are relocated every 4 to 6 years. Sometimes the move is minor and of only a few rods, rendered desirable by disrepair of the houses. At other times, the change may involve a shift of as much as 15 miles or more. Such a new location means a time of food shortage until the new plantings come into production, though this is generally provided against to some extent by building a temporary village until new gardens are established and deferring complete transfer to the new site until a food supply is reasonably assured. Any one or a combination of several causes may be responsible for the movement of a village. Fundamentally, it is forced by destructive exploitation, for each year decreases the productivity of large acreages and forces additional clearing, so that cultivated fields retreat farther and farther from the settlement until distances become so great that relocation is desirable. The occasion for the shift, however, that is, the factor which determines the exact time when the village is moved, may be war; the hostility of neighboring tribes; the ravages of fields by animals, particularly elephants; deaths; or even superstition. With abandonment of the old village, it soon decays and its site is recaptured by forest vegetation.

These migrations of the Fang from one site to another, often briefly to locations near trading posts until disillusionment follows, when it becomes evident that the white man's goods can be secured only in exchange for the products of forest and cultivation and other results of labor, are a continuing occurrence. Following the streams, they have carried the Fang from their ancestral home, upstream in the Ogowe basin, almost to the sea everywhere, and to the sea in places. These lines of migration are marked by devastation in the forest. The former growth is replaced by worthless brush, certain elements of the native vegetation such as the rubber vine being destroyed completely. Along them as well, land capable of producing the plantain or banana shrinks in extent, for agricultural nomadism tends to lessen opportunity for cultivation to the point of virtual extinction. This "robber economy" of the Fang was one common in many parts of the world at an earlier time, even in our own country in colonial Virginia; today, commonly confined to less well-developed regions, it is found frequently in areas of tropical forest in South America and elsewhere, as well as in Africa.

Other Primitive Agricultural Occupation of Tropical Forest Land. Primitive agricultural use of tropical forest areas is not necessarily associated with a continually shifting pattern of village location. However, the practices of such agriculture always necessitates either short time or intermittent use of any clearing under cultivation by reason of the small amount of available plant nutrients in soils where rainfall is heavy, temperatures are high, and leaching is, therefore, both active and continuous. This is because, under primitive cultivation, little if any provision is made for artificial replenishment of the supply of plant nutrients, when their amount is depleted by cropping. Nevertheless, this does not preclude the possibility of support of a sparse, fixed population, if the amount of tillable land is ample. Thus the native agricultural population of southern Nigeria is sedentary. This is made possible by the practice of what is known as "bush fallowing," that is, growing a crop, preferably each fifth or eighth year only, with bush occupying the acreage which is fallow or uncultivated. In addition, the "woman's land," or the gardens near the villages, is fertilized with household and animal wastes.

The Djuka. An interesting example of the practices of primitive agriculture in the Americas is afforded by those of the Djuka of Dutch Guiana, in northern South America. These Bush Negroes are descendants of slaves who escaped from their masters to a life of freedom in the forest, there to establish settlements which have endured for more than two centuries. So successful were they, indeed, that all efforts on the part of the Dutch to destroy them failed. Thus the Djuka today do not regard themselves as the inferiors of the whites, but as their equals, paying only nominal allegiance to the government, and refusing to take orders, though sometimes willing to accommodate with their services.

The Homeland of the Djuka. The homeland of the Djuka, which begins a few miles inland from Paramaribo, includes the territory bordering the middle and upper stretches of the larger rivers of central and eastern Dutch Guiana,

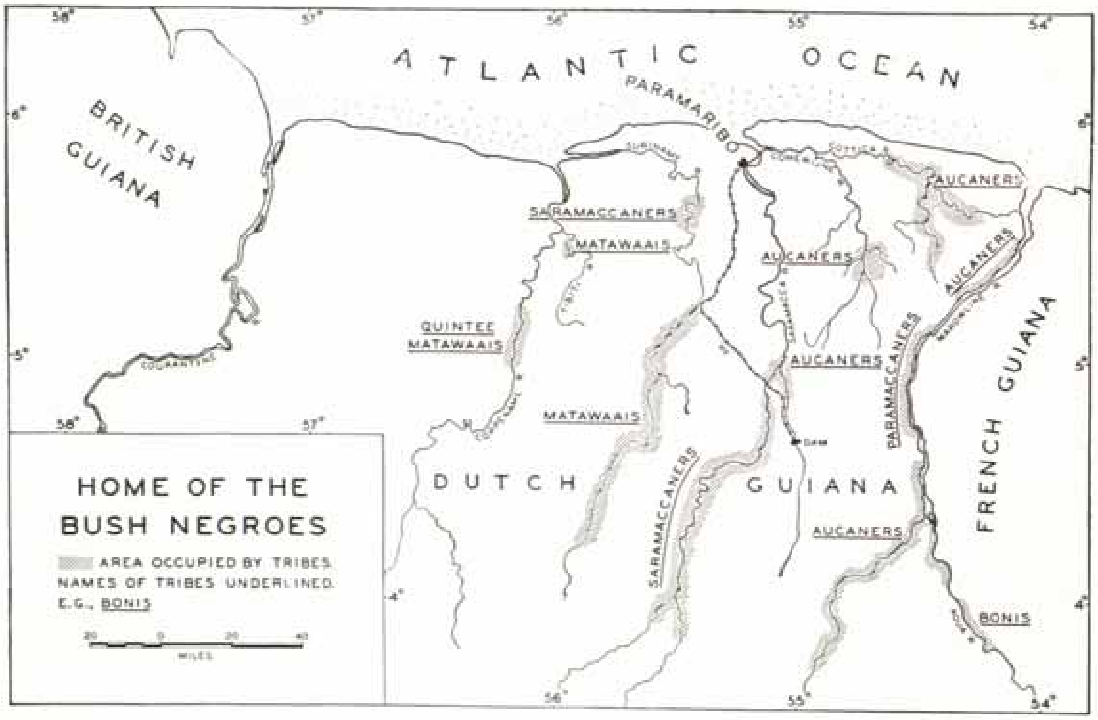

FIG. 281. The homeland of the Djuka, in central and eastern Dutch Guiana, northern South America. (After M. C. Kahn.)

with a small and narrow extension into French territory, along the Marowline River. In this country live approximately 22,000 Bush Negroes: six tribes in all, with the Saramaccaners making up nearly 60 per cent, and the Aucaners 25 per cent of the total number. None of the other four has 1000 members. Each of these tribes, which represents the descendants of a group of escaped slaves, is independent, with its own territory, government, and with but few relations and no intermarriage with the others.

Elevations of the territory occupied by the Bush Negroes vary from less than 500 to a maximum of 1500 feet above sea level. Thus they are too slight to materially affect the temperatures of these low latitudes, from 3° to 6° north of the equator. Therefore the average temperature for the year isabout 80° F., with a departure of less than 5 degrees in any month. Because of the well-distributed annual rainfall of from 80 to as much as 120 inches, the ground is wet and the air is moist much of the time, sensible temperatures are high, and health conditions are generally considered poor for white populations.

Everywhere the forest forms a dense cover, interrupted only by the streams; even these are confined by walls of impenetrable growths of great trees and smaller forms of vegetation, including lianas or vines, which shade their waters. Animal life is abundant and varied. On the land, it includes among others the armadillo, agouti, peccary, jaguar, puma and other cats; in the water, the alligator and many species of fish, including the carnivorous piranha, only 6 to 8 inches in length, but traveling in schools of such size as to make bathing dangerous. In the tree tops, there are many brightly colored birds: parrots, parakeets, and macaws. Others, such as kingfishers and great waterfowl, frequent the stream margins. Reptiles, including both poisonous snakes and nonpoisonous kinds like the boa constrictor, are native to this area, and insect life is very abundant: vicious fire ants, carnivorous mosquitoes, butterflies of all sizes and colors, and many more.

Villages, Highways, and Transportation. The villages of the Djuka are located in small clearings, hemmed in by forest. They are always near

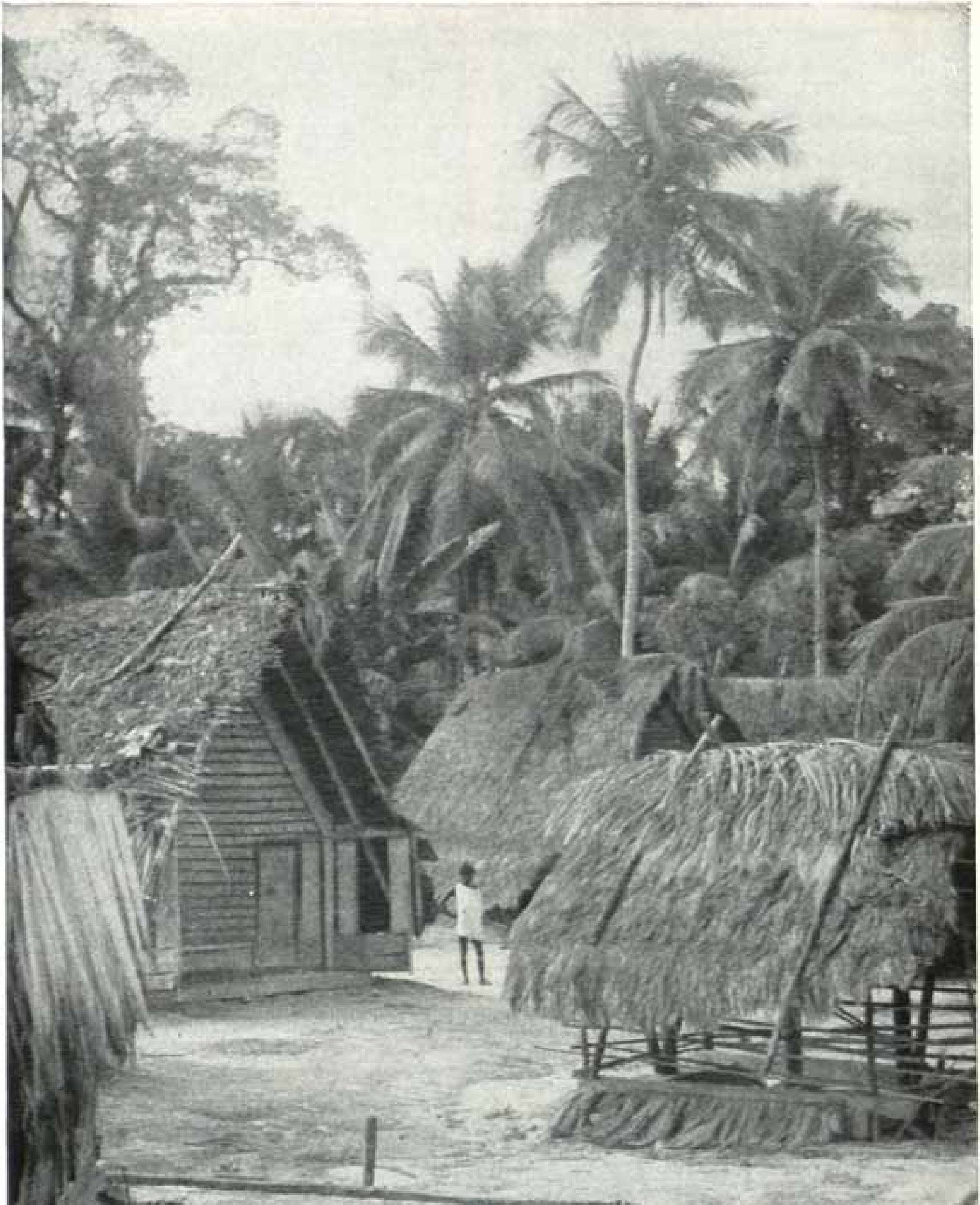

FIG. 282. A Saramaccaner village on the Surinam or Saramacca River, Dutch Guiana. The houses, with thatched, projecting roofs, and walls of woven reeds and grasses, are scattered somewhat irregularly about the clearing. At the right, in the foreground, is a "God house." Beyond the bare clay of the clearing, the forest crowds the village. (Courtesy of Fred Hardenbrook.)

rivers, which are the highways, but from ¼ to ½ mile removed, to escape inundation at times of flood. Often, they are on the upstream side of rapids or falls which obstruct navigation. Though normally out of sight from the river, their presence may be detected by the corials or dugouts tied up at the river bank.

The villages vary greatly in size, some of the smaller ones consisting of only eight or nine huts. These are scattered about the clearing in no particular order, interspersed with occasional palm and breadfruit trees. The remainder of the clearing is bare clay, except for an occasional flower garden at its center and scattered "god houses," where the fetishes stand. The villages are universally clean and sanitary, for garbage is dumped into the stream below their sites, or is fed in part to the chickens, and other filth is not allowed to accumulate around them.

Houses and Household Furnishings of the Djuka. The walls and roofs of the houses are made of grasses and reeds, woven so tightly that they shed rain; the supports are tree trunks, often elaborately carved. Roofs overhang, keeping the interior of the hut cooler; the extension of 3 feet or more in front affords shade for "black palaver." When the owner dies, his hut is abandoned to decay.

The houses are furnished very simply. Hammocks of woven cotton or grass are used by the men, sleeping mats by the women. For containers, the Djuka use crude, black clay pots of local manufacture; calabashes and gourds; and, for carrying yams, rice, and other foodstuffs, roughly circular baskets. There is no working of iron, for there is no local supply of iron ore, but hardwood, carved by the men, is used extensively. Some of the utensils, such as the cassava squeezers, are patterned after those of the Indians, but most of them are of West African types and patterns.

Clothing of the Djuka. Relatively little clothing is worn, except where the missionaries have "incongruously brought their tribal taboos into the bush," where exposure to heavy rains is common. A loin cloth of brightly colored cotton, held in place by a string of plaited grass, is the only garment of the men when at work; on other occa-

FIG. 283. A Djuka corial or dugout negotiating a rapids, indicating that, though rivers are the highways, they are often poor. Note how the forest walls in the river, and the small amount of clothing worn by the Djuka engaged in pushing the dugout upstream against the swift current. (Courtesy of the Netherlands Information Bureau.)

FIG. 284. At the left is one of the men of the village shown in Fig. 282, wearing both the usual loincloth and a toga or "camissa." In his right hand he holds a bush knife or machete; in his left, a seven-foot canoe paddle. In the background is the tightly woven wall of one of the houses, with an elaborately carved doorway.

At the right is one of the women of the village, dressed in typical native attire. She is engaged in pounding cassava flour with a carved wooden pestle. In the background is an open-front cooking hut or one of the communal kitchens. (Courtesy of Fred Hardenbrook.)

sions, a toga or "camissa," made by sewing together pieces of cloth of gaudy patterns and colors, is sometimes worn over the shoulder. The women wear either one or two garments. The one always worn is a piece of cloth, wrapped around the body from or below the breast to the knee, sometimes supplemented by another, clasped at the shoulder. Children below the age of ten commonly go naked in the villages.

The Djuka Food Supply. In their practice of agriculture, the Djuka till small fields of about ½ acre in size, located from ¼ to as much as 5 miles from the villages. The men prepare these fields for use by clearing away the brush with axes and bush knives or "nefee." Then the clearing is turned over to the women for planting, care, and harvest, in which the men assist only when pests threaten yields.

The staple food of the Djuka is cassava or manioc, obtained from a root which, after extraction of the prussic acid present, is dried and made into a flour. This is baked in cakes or stewed with fish. Maize, grown to a limited extent, also affords part of the food supply, the grain being roasted until hard, but never eaten green. Upland rice, threshed in wooden troughs with pounders, is likewise a crop on limited acreages. The Djuka also grow yams, but not white potatoes; some sugar cane; and, occasionally, bananas, coconuts, pineapples, and breadfruit. Palm oil, made from the nuts of certain palms, furnishes "Mareepa," the native equivalent of a soft drink.

To supplement the supply of food from the gardens, the Djuka—men, women, and children—engage in fishing. Hunting also contributes to the food supply to a less important extent. Both guns and bows and arrows are used, the latter often preferred because they make no noise. With these weapons, the Djuka hunt the red howler, the tapir or bush cow, the agouti, the peccary, the armadillo, the bush turkey, and the bush hen. In this hunting, they are aided by mangy terriers. Some game is also secured by trapping. The products of the chase, however, do not afford the major part of the food supply, but only an occasional treat.

Other Economic Activities of the Djuka. Since some wants cannot be met directly from local resources, but must be satisfied by barter, the Djuka exploit the forest resource to obtain material for trade. They first locate a tree of the desired species, as near to the water as possible. Then they clear away the growth around it; otherwise it would be held upright by the tangle of lianas, even if cut. After it is felled, it is squared, hauled to the river, and tied to others by lianas to form a raft, which is floated downstream to the white settlements. Since these logs are too dense and heavy to float when green, each must be supported between two others of lighter, softer wood. When the raft reaches Paramaribo, it is broken up and the logs are exchanged for gunpowder, percussion caps, tobacco, salt, cloth, iron, implements, mirrors, and similar items.

The Bush Negro and His Future. The Bush Negro leads an essentially self-sufficient, happy, and carefree life in his tropical forest environment, for his wants are few and these are easily satisfied. Almost endless visiting and palaver occupy much of his leisure, and his limited contacts with others cause him to be but little disturbed as yet by the happenings of the outside world. Before many years, however, despite his continued retreat into the bush, necessitated by decrease in productivity of the fields under exploitive use, the encroachment of civilization may be expected to wipe out these last remnants of the trans-

FIG. 285. Djuka drummers and elaborately carved drums, with hut in the background. Note the dress of the drummers. (Photo by Fred Hardenbrook, Courtesy of the Netherlands Information Bureau.)

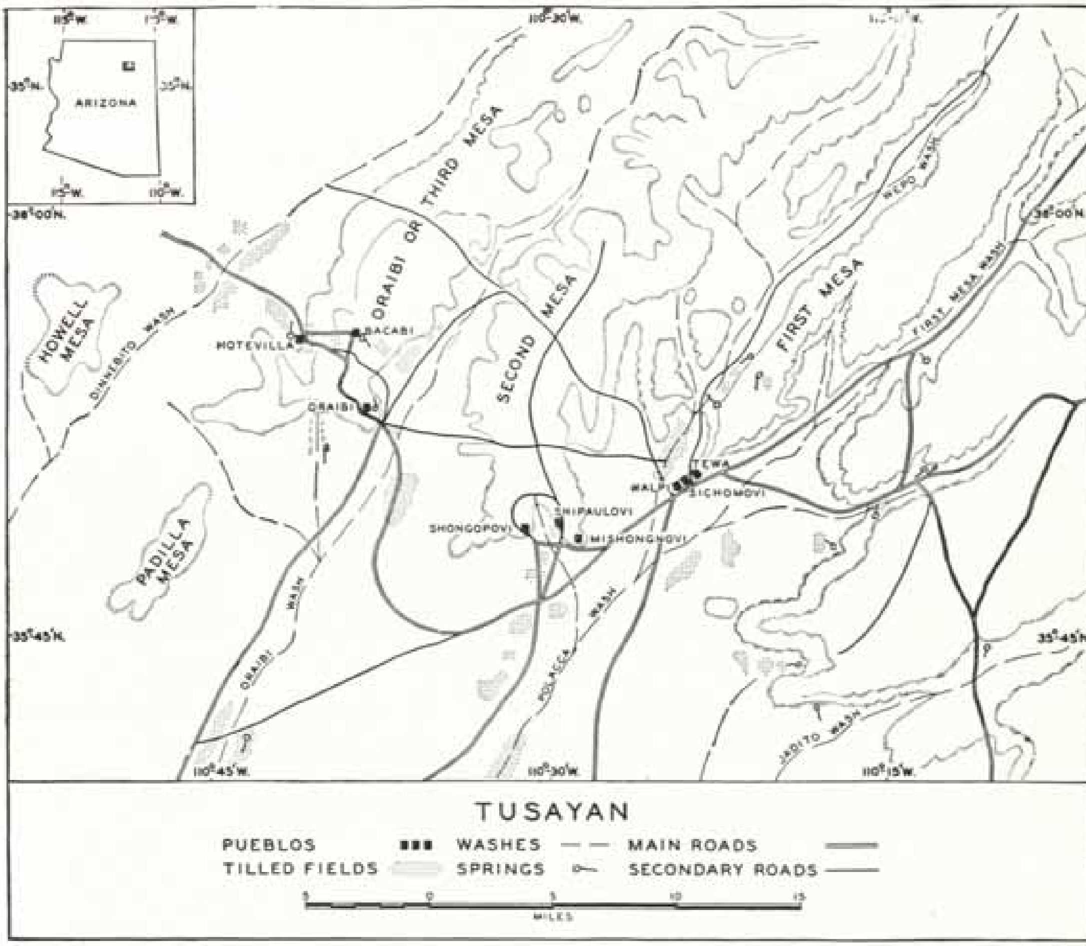

FIG. 286. The Hopi country of Arizona includes the area between Jadito and Dinnebito washes, less than 40 miles apart; its north and south extent does not exceed 20 miles.

planted primitive culture of West Africa; the Bush Negroes will disappear as a separate population group; they may even be forgotten except as their part in early Guiana history may make them live on the printed page. Today, however, they still exist as a primitive, semiagricultural population, and serve to illustrate such a method of life.

Primitive Indian Agriculture. Primitive agriculture, similar to that practiced widely during the earlier periods of history, persists not only in the forests of low latitudes, but in other areas as well, wherever opportunity presents and intrusion of advanced populations has not displaced the older practices. Thus primitive Indian agriculture still exists, with slight if any modification, in many isolated, less attractive portions of both low and intermediate latitudes in the Western Hemisphere. The agricultural system, practices, crops, and habits of life of the Hopi Indians of Arizona will be considered as illustrative of those of such primitive Indian agricultural populations of the drier areas.

Tusayan, the Hopi Indian Country. The Hopi country, known to the Spaniards as the "Province of Tusayan," is located about 65 miles north of Holbrook and Winslow, Arizona. It today includes the 750 square miles of territory which lie between Jadito and Dinnebito washes, less than 40 miles to the east and west of one another, with a width nearly half that great. In this area, live approximately 2800 Hopi Indians. The bal-

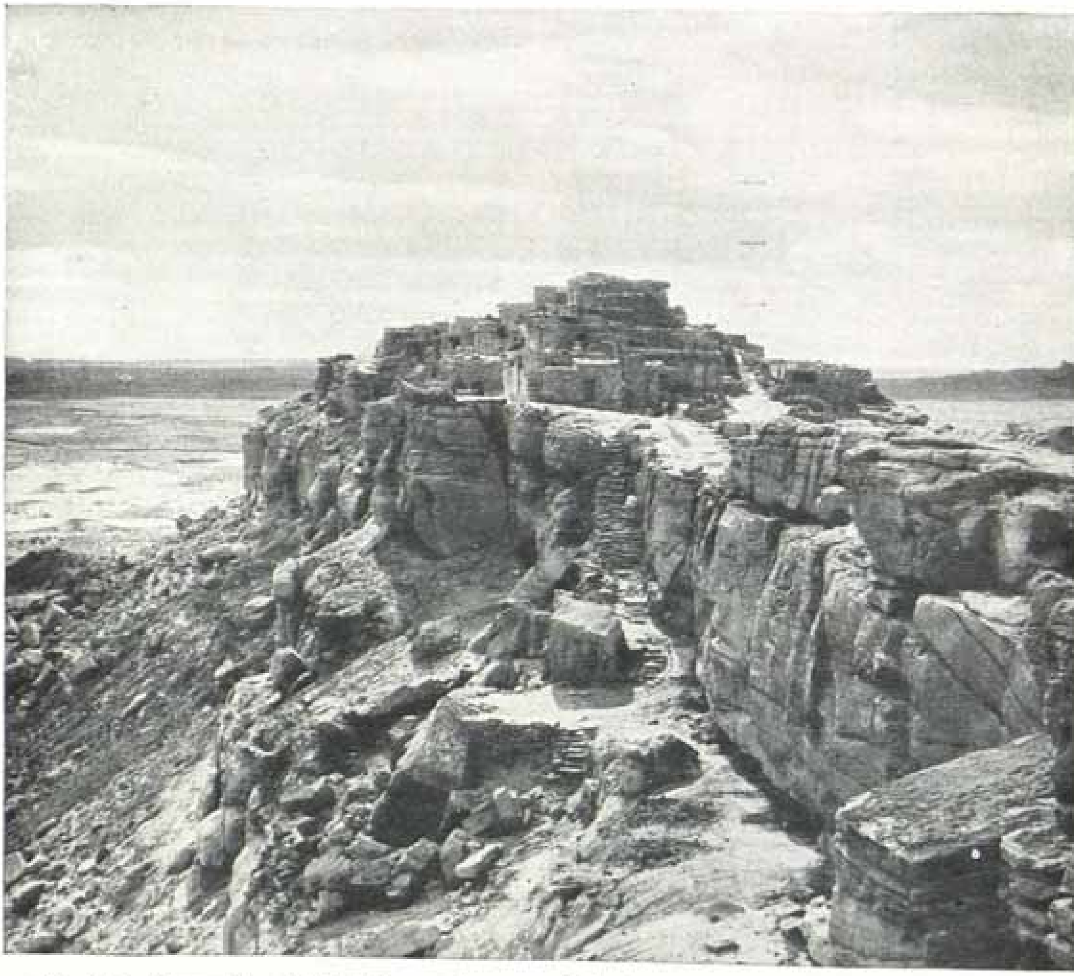

FIG. 287. The pueblo of Walpi, the southernmost of the three villages on the First Mesa. Approach to the village, located on the edge of the flat-topped mesa, is by the stone stairway; the terrace at its left serves as a corral. Note how the buildings blend into the barren, rocky landscape. This pueblo, with a population of 161 persons, is one of the smaller of the Hopi villages. (Courtesy of the Atchison, Topeka and Santa Fe Railway.)

ance of the Hopi Indian Reservation, established in 1882 with an area of 3920 square miles, is peopled by Navajos. At one time, the Hopi lived, undisturbed by enemies, near the fields which afford most of their support, the name "Hopi" meaning "peaceful people." Later, when threatened by migration of warlike, marauding tribes, they retreated to mesa villages, the pueblos, which could be easily defended when attacked. At present, these are located on three fingerlike projections from the great Black Mesa of the Arizona Navajo country, on each of which are three villages, with populations of from 116 to 400 persons.

The Hopi Villages. The drab, gray pueblos, located on the edge of cliffs, are built on the bare rock of the capping sandstone layer of the mesas, angular erosional remnants with flat tops and steep facing slopes, characteristic of dry areas. Approach to the villages, which blend into the barren, rocky landscape, is by steep trails up the face of the cliffs which border the mesas, making use of joints or breaks in the rock as locations for the stairways. Terraces formed at lower levels by the outcrop of resistant sandstones, which are interbedded with the softer shales of the horizontal rock layers of the mesas, serve as locations

for protected corrals; the higher ones for sheep and cattle; those somewhat lower, for swine. On each of the three mesas, the villages are close together and they may even merge; those of different mesas may be several miles apart.

To afford additional security, houses, rising to as many as four stories, are built solidly around courts, with setbacks on the court side, so that the stories rise steplike, one above another. Formerly, there were no doorways in the first story, entrance being by holes in its roof, reached by a crude ladder. Walls are of roughly dressed and poorly laid stone, plastered with adobe and whitewashed with kaolin, a clay available in the shale of the mesas; the flat roofs are covered with brush and clay, supported by juniper beams and poles. Fireplaces, equipped with hoods and chimneys, are located in the corners of the rooms.

The water supply of the villages is obtained from the scanty flow of springs at the base of the mesas, along the line of contact of porous sandstones and impervious shales. Fuel is used sparingly, since it is scarce and difficult to secure, for over-grazing and collection for domestic use have destroyed most of the vegetation near the villages. Refuse is thrown over the cliff, some to land in the corrals, but as much lodges along the approaches, the villages are filthy, despite the dry air, sun, and strong winds. Such practices, plus the compactness of the pueblos and their insanitary condition, increase the prevalence of disease, tuberculosis and trachoma being common, and occasional outbreaks of measles and smallpox causing many deaths.

Agriculture and Food Supply of the Hopi. Each family tills from 2 to 10 acres, in small patches which often shift yearly, these fields being located near washes, sometimes as much

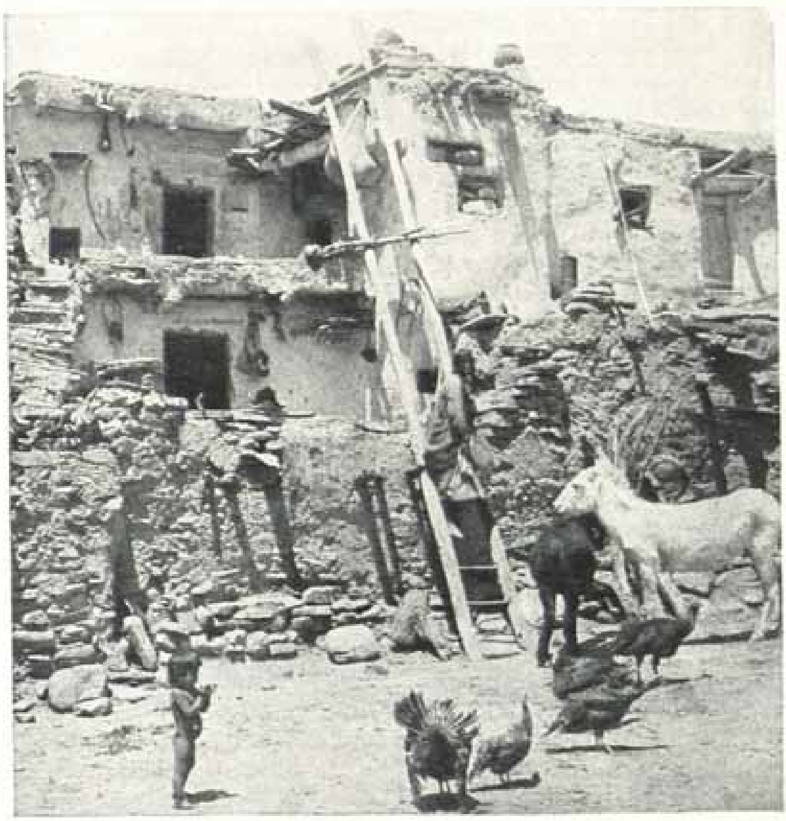

FIG. 288. Portion of the pueblo of Mishongnovi, on the second Mesa. This village has a population of 266 inhabitants. Note the crude masonry and the ladder used to afford access to the upper stories. (Courtesy of the Keystone View Company.)

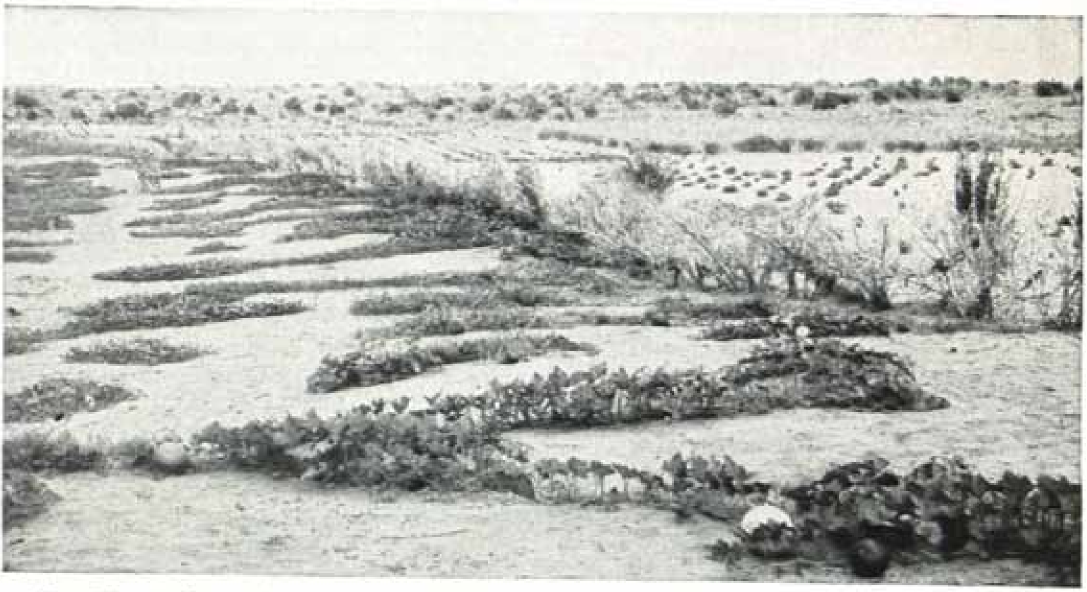

FIG. 289. Melon patch in dune sand, about one-quarter of a mile from Hotevilla, on the road to Oraibi. (Courtesy of the U. S. Soil Conservation Service.)

as 15 and, in earlier times, 45 miles from the pueblos. They are farmed under difficulties, for this is a dry region with a poorly distributed rainfall of but slightly more than 10 inches. The spring months are very dry; even in July and August the 6 inches or more of water normally fall in a few heavy showers or cloudbursts. It is these downpours which make agriculture a possibility for, at times of their occurrence, the fields bordering the washes are inundated, thus supplying the necessary water. Often, however, some of the fields will be stripped of soil or buried by sterile sand, so that only a fraction of the area planted can be harvested. Further, arroyo cutting or gullying has of late years become so serious that, where floodwaters formerly spread a mile or more over the land bordering the washes, they are now confined to the new and deeper channel, thus causing shrinkage of the cultivable area. Because of elevation, temperatures are not particularly favorable, for they rise slowly in the spring, frosts being common until past the middle of May and occasionally occurring as late as the first part of June. To drought, frost, and flood, are added the attacks of pests: worms, birds, and mice. Thus the Hopi farmer has many handicaps and is faced with numerous hazards, the chief of which is, of course, the danger of drought. Even despite careful, painstaking practices in agriculture, crop failures from this cause are so common that food must be stored to tide over one or two years of possible complete crop failure. Rains are so vital and the conservation of water is so necessary, indeed, that they dominate religious beliefs and practices, including that notable ceremony, the August snake dance.

Crops raised include corn, beans, melons, squashes, pumpkins, and wheat, all except the last grown from time immemorial. Of these food crops, corn is the most important. Some early corn, dependent on stored water of the previous year's rains, is planted in favored locations during April and harvested about July 25. The late or "pig corn," the important crop, is planted in June, replanting continuing to July, when the rains occur. To increase the probability of satisfactory yields, fields are tested for moisture before planting, and hills are spaced 6 feet apart to avoid undue drain on the small supply of water available. In planting the crop, a hole 1 foot deep is made with an iron pipe, partly to loosen the hard surface layer. Then this is filled with loose dirt to within 5 inches of the surface and the corn is planted, plenty of seed being used because of the large percentage of loss from cutworms, birds, field mice, and wind-driven sand. In former times, a planting stick rather than an iron pipe was used to make the hole, which

affords some protection to the young shoots of corn, as well as assures more moisture for their root systems. The corn grown is a drought-resistant variety, only a few feet high, but yields are fair in good years. Most of the corn is picked green, cooked in its husks, and allowed to dry, then reheated before use, though some is allowed to mature on the stalks and then ground into meal. Beans, the principal variety the gray speckled pinto, are eaten green until the vines are pulled; then they are shelled and stored. Melons are likewise eaten fresh during the summer but, with the coming of frost, all the green ones are harvested, these keeping until January or February. Wheat and potatoes are of less importance and are recent additions to the food crops. Among the fruits, peaches, grown on slopes with effective air drainage, are the most important. Of the non-food crops, cotton is grown, but the acreage is small.

The Hopi own 4500 cattle, 14,200 sheep, 7500 goats, 3600 horses, burros, and mules, in addition to hogs and chickens. However, the animal industries, though supplying meat, wool, skins, and transport, are secondary to other agricultural activities.

Other Economic Activities of the Hopi. Other economic activities include basketry, the manufacture of pottery, weaving, and silver-working, with the first two the more important. All of this work except the making of baskets, but including the weaving of both cotton and wool, is done by the men, the best Indian weavers of the Southwest. They likewise till the fields, harvest the crops, tend the flocks, secure the fuel, and supply the building material for the pueblos. These are built by the women, who thereafter assume possession of the house and ownership and care of all the material wealth, including the harvested crops.

QUESTIONS AND EXERCISES

1. When and how did agriculture probably have its beginnings?
2. Locate and describe the physical environment of the area occupied by the Fang.
3. Why is it proper to describe the agriculture of the Fang as "exploitive" in type? What are the disadvantages of such a type of agriculture?
4. When are the larger fields of the Fang cleared? Why? What crops are grown? For how many years can a field be used? Why for so short a period? Why does the type of agriculture practiced by the Fang necessitate frequent shifts of location of the villages?
5. What care do the Fang give the crops after planting? How important are the animal industries among the Fang?
6. To what extent do the Fang depend on wild plant and animal life to satisfy their needs? What do they obtain from such sources?
7. Where are the Fang villages located? Why? What is their plan and type of construction? How is their protection assured?
8. How often are the Fang villages relocated? Describe the process of relocation. What causes the relocation? Why may this be a time of food shortage? Why has such a relocation of the villages caused a downstream migration of the Fang?
9. Who are the Djuka and where do they live? Why do they consider themselves the equals of the whites?
10. Describe the physical environment of the territory occupied by the Djuka. What are the numbers of the Djuka? How many Djuka tribes? How did these tribes originate? What are their relations with one another?
11. Where are the Djuka villages located? What serve as highways in this area? Describe a Djuka village: its plan, houses, household furnishings, and sanitary conditions.
12. How do the Djuka dress? Why is too much clothing a disadvantage?
13. Describe Djuka agriculture as regards the location and clearing of the fields, the crops grown, and their care.
14. In what economic activities, other than agriculture, do the Djuka engage?
15. Compare the living conditions and economic activities of the Fang and Djuka. What is the probable future of such primitive semiagricultural populations of tropical forests?
16. Are all primitive agricultural populations of the tropics migratory in their habits? If not, how do they find it possible to practice agriculture for long periods of time in a given area? What is meant by "bush fallowing"?
17. What are the boundaries and the population of the Hopi country? Describe the physical environment of this area.
18. Where are the Hopi villages located? Why? What are their populations? Describe the plans of these villages and the construction and ar-

rangements of the houses. Where are the corrals for the animals located? What is the source of the village water supply? Why is disease prevalent in the villages?

19. Where are the cultivated fields of the Hopi located? Why? How far are these fields from the villages? When are the fields planted? Why? How are they cultivated and what crops are grown?

20. What other economic activities of the Hopi supplement the returns from agriculture? What is the division of work between the sexes among the Hopi? In whom is the ownership of material possessions vested? Why?

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This reference supplies a somewhat more extended description of the homeland and of the economic and other activities of the Fang than that in your text.

Bryan, Kirk, "The Papago Country, Arizona," *Water Supply Paper 499*, U. S. Geological Survey, Washington, 1925.

This paper affords an adequate description of the physical conditions of the Papago Country, where the Papago Indians carry on agriculture under conditions even more unfavorable than those of the region where the Hopi live.

Gregory, H. E., "The Navajo Country," *Water Supply Paper 380*, U. S. Geological Survey, Washington, 1916.

This paper describes in detail the physical setting of the region occupied by the Navajo and Hopi Indians.

Kahn, M. C., *Djuka*, Viking Press, New York, 1931.

This publication is an interesting popular account of an expedition into the back country of Dutch Guiana and contains a detailed account of the Djuka and their activities.

Chapter Thirty-One

ORIENTAL AGRICULTURE

The Development and Effects of Agriculture. Agricultural use of the land always modifies the natural environment, even though practices are those of primitive, migratory production, characterized by short-time use of tracts cleared and frequent shifts of location of cultivated fields. The change produced, however, reaches its maximum in regions occupied by more advanced, sedentary populations. In such areas, not only is the natural cover of grass or forest removed and the soil tilled, but crops, frequently new to the environment, are grown on the same fields for many years in succession. This is also generally accompanied by the production and use of various domestic animals. In fact, few of the economic activities of man alter the natural environment as fundamentally as do the practices of sedentary agriculture.

Such agricultural use destroys much of the native plant and animal life, substituting forms new to extensive, continuous areas. Not only are useful plants and animals introduced, but others as well, which frequently displace many of the native species not destroyed by actual cultivation and grazing. Thus the flora and fauna become altered so greatly that reconstruction of past conditions from present evidence is often difficult.

Accompanying the inroads of cultivation and displacement of native plants and animals, highways, both improved roads and rail lines, appear where formerly only game trails and stream courses interrupted the continuity of the cover of native vegetation. Houses to accommodate the sedentary agricultural population dependent on continuous use of definite fields dot the landscape, and urban aggregations spring up at irregular intervals to serve the needs of the surrounding agricultural areas. In these towns and cities, the maximum of alteration is manifest, for change there may be so extensive as to modify both surface materials and features and cause such essentially complete destruction of native life forms that cultural rather than natural features dominate the landscape.

The beginnings of modification of extensive, continuous areas by sedentary agricultural activities had their origin in two centers: one in southern and southeastern Asia; the other at the eastern end of the Mediterranean. From the first of these two centers, sedentary agriculture pushed to the north in China and into Japan; from the second, it spread to southern and eventually to western and northwestern Europe, and thence to the New World, Australia, northern Asia, and southern Africa. Today, its advances have been so extensive that the agricultural frontier has disappeared in most parts of the world, though other frontiers of at least as great significance and promise remain to challenge human enterprise and endeavor. In the relatively few places where the agricultural frontier, either temporary or permanent, still persists, it lies along the borders of cold, dry, or very wet areas, into most parts of which profitable agriculture can advance only with great difficulty, if at all, and only where means of offsetting present handicaps have been devised.

The exact character of the advance of agriculture varies both with the region invaded and the population group which develops the area into which agriculture pushes. Physical conditions everywhere limit agricultural opportunity by favoring or refusing the possibility of economically important yields of definite crops. For example, one area may permit profitable production of rice, sugar, and other crops which can be grown effectively under similar conditions; an-

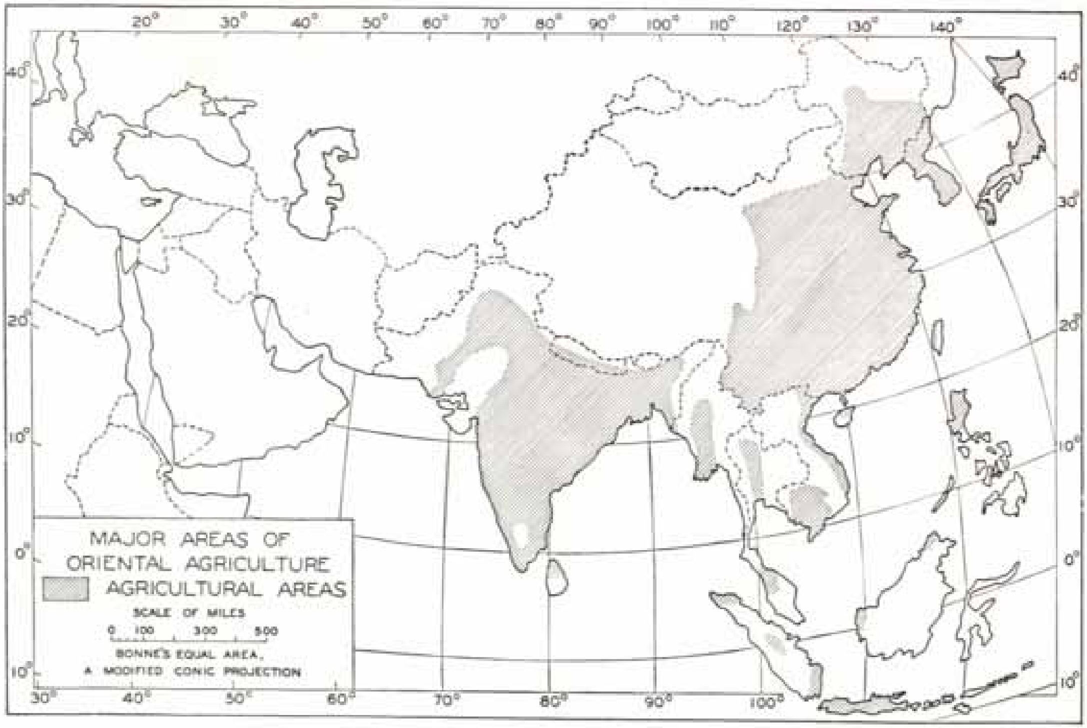

FIG. 290. Major regions of agricultural use of the land with Oriental practices.

other, of wheat, barley, flax, and those crops with comparable climatic and soil requirements. The farmer is therefore limited by environmental conditions in his choice of crops which can be grown profitably. Thus the character of the advance is affected by environment. However, choice of the specific crop to be grown is the result of individual, personal decision, which likewise influences the type of cultivation and often the objectives of production as well. Sometimes, therefore, cultivation will be intensive; sometimes extensive; sometimes few animals will be kept and used; again, by contrast, the animal industries will bulk large in the regional economy. Thus decisions of the population group affect the rate and character of the advance of agriculture.

Today, in addition to primitive, sometimes migratory production, there are two contrasting agricultural systems: one, the Oriental, which spread from the southern and southeastern Asiatic center; the other, the Occidental, from the center at the eastern end of the Mediterranean. Which of the two is practiced affects both the extent of the potential agricultural area and its possible use. We shall consider the first of these two systems in this chapter; the second, in chapters which follow.

Oriental Agriculture. Oriental agriculture is characterized by small farms, intensive cultivation, little use of machinery, much hand labor, and production of relatively small surpluses of most agricultural commodities, particularly of foodstuffs, few of which enter world trade in important quantities from areas where this type of agriculture is practiced. It is, therefore, an essentially self-sufficing, garden type of agriculture. Where highly developed, it permits support of almost incredibly dense agricultural populations, as dense as those of highly industrialized areas, by ensuring maximum yields at all costs. In some cases, in fact, the returns from such use of the land represent the fruits of labor rather than the bounty of nature, in a very real sense. Such practices mean, not alone expenditure of effort out of all proportion to returns, but as well a choice of crops dictated by the quantity of food obtainable rather than by the quality of the supply secured. Thus they represent appre-

ciable sacrifice to ensure comparative security, attained by laboriously achieved, small returns. This results in freezing the standard of living at a low level. Obviously, they preclude the possibility of expansion of agriculture into submarginal agricultural areas, where use of machinery is necessary to secure profitable production. The general form of such Oriental agriculture is conditioned by environmental opportunity; the exact pattern by human choice. Thus Oriental agriculture is of two general types: (1) that of the rice lands, and (2) that of areas used for growing other small grains and legumes such as the soy bean.

The Rice Lands. The rice lands support approximately one-third of the earth's total population, though comprising considerably less than 8 per cent of its land surface. Concentration of such a large number of people dependent on agriculture on this small fraction of the earth's surface produces the maximum densities of rural population known. In the rice-growing provinces of the lower Yangtze Valley, for example, the number of inhabitants to the square mile in purely agricultural areas varies from 980 to 6880, according to Mallory. Certainly, few areas, even those which are highly industrialized, can match these densities. Such concentrations are made possible by the fact that, under favorable conditions and the intensive cultivation of Oriental agriculture, a given area of land supplies much more food than it would if used to produce other cereals.

Not only does rice afford a large amount of food from each acre of land under cultivation, but it is likewise a crop which can be grown with few and simple tools, so simple that the type of production employed in Oriental agriculture is sometimes described as "hoe culture." This is a great advantage in such areas, where individual landholdings are commonly small and a large investment in expensive tools and machinery

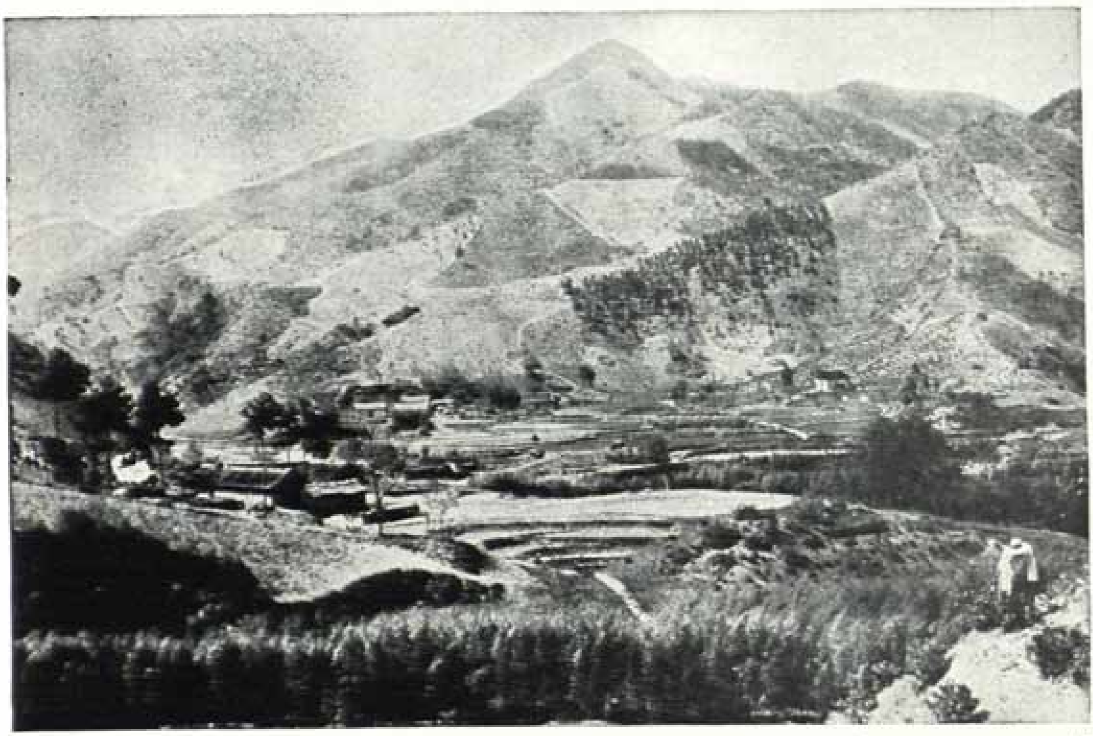

FIG. 291. An agricultural scene in the Hwai catchment area, central China. Production, except as carried up the lower slopes by terracing, is confined to the flat alluvium of the valley floor, which is well adapted to growing rice, the major cereal crop. Other crops grown in this area include wheat, maize, peas, hemp, tea, and bamboo. Of this list, the annual crops are grown on the rice fields during the winter months; the bush and tree crops, tea and bamboo, on land unsuitable for other production. (Courtesy of the U. S. Soil Conservation Service.)

FIG. 292. A remarkable example of terracing for rice production by the Ifugaos, Mountain Province, P. I. (Courtesy of the U. S. Soil Conservation Service.)

would be economically unsound as well as impossible of realization by the farmers. In addition, rice is well adapted to the topographic, soil, and climatic conditions of the rice lands, whereas most other cereals are not. Therefore the crop is one well suited to most of the areas where it is grown as the major cereal: warm plains regions with dense agricultural populations, in general with but relatively slight commercial and industrial development.

The Rice Crop and Its Habitat. Rice is a crop of plains areas which are or can be flooded, for it must be grown on fields covered by standing water. The water, moreover, must be kept at an approximately uniform depth of 6 inches during the period of growth, hence the fields in rice must be nearly level. Where rice is raised on even moderate slopes, therefore, it is necessary to resort to terracing and to modify the natural slope between the retaining walls sufficiently to insure tolerably level surfaces for the individual fields where the crop is grown. Where terracing is not necessary, the land may be so flat and poorly drained that the paddies or fields are wet and often under water in places, even during their preparation for planting, so that the farmer must work in mud as much as a foot or more in depth. Though this is disagreeable, it simplifies the problem of working the soil with crude plows and hand tools for, when wet and soft, the soil turns over more easily than it would were it dry and hard. Such wet land, well adapted to growing a swamp crop such as rice, is unsuitable for the production of other cereals, except after drainage, which is always expensive and sometimes virtually impossible. Occasionally, such wet fields are ridged by hand labor, so that strips of dry soil, on which crops may be planted, are exposed. These are winter crops. Though this is sometimes done, yields are often low, because of poor soils, so that the venture may be uneconomic.

Rice is believed to have been native in India

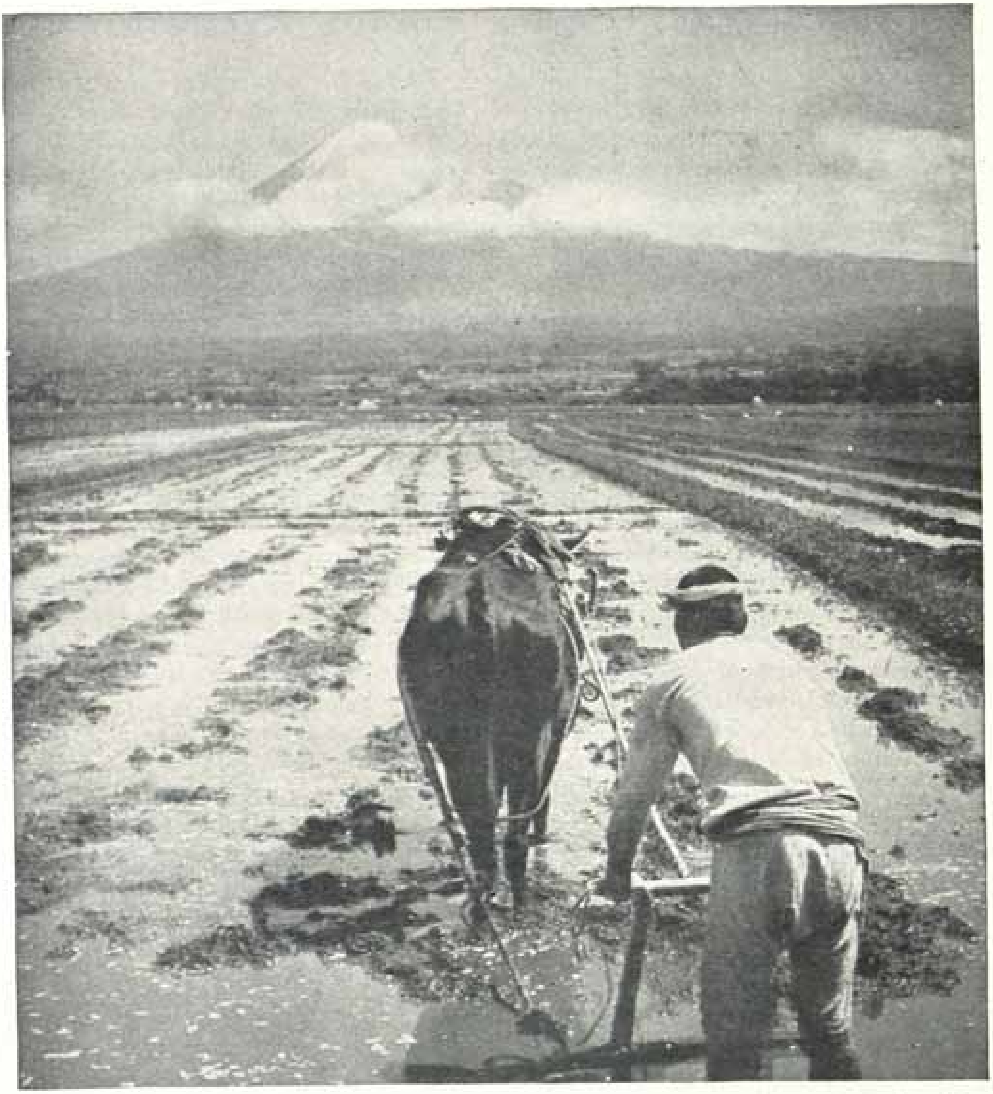

FIG. 293. Rice land in east central Honshu, with Mt. Fuji in the background. Cattle rather than horses are commonly used as plow animals in preparing the land for planting where it is so wet. (Courtesy of the Keystone View Company.)

and adjacent areas of southeastern Asia, and possibly in South China as well. From its wild ancestor, the seed of which was probably gathered and used as food by many generations of migratory, primitive native populations, have evolved the many types of rice grown today. Some of these have been so specialized by careful selection and breeding that they can be grown successfully far to the north of the original home of the cereal; others of less importance are adapted to upland cultivation. From the original center of dispersal, rice growing spread to the islands off southeastern Asia, notably to Java, but to a less important extent to Sumatra, Borneo, the Celebes, and New Guinea. To the north, its cultivation eventually extended as far as Korea and into the islands of Japan, today one of the great rice-producing areas of the world. To the west, expansion was for many years checked by aridity, and it was not until modern times that rice growing hurdled this barrier and invaded the Western world to any appreciable extent. Where grown

elsewhere than in the Orient, the crop uses limited areas of flat, wet land, poorly adapted to other crops or entirely unsuited for their production, and cultivation is much the same as that for other cereals grown under Occidental systems of agriculture. Thus, even today, most of the rice grown, 90 per cent or more, is produced by the rice lands of the Orient.

Rice Growing and Progress. Production of rice generally necessitates cooperative effort, for much work is commonly needed to prepare the land and secure the supply of water necessary for irrigating the fields. With initiation of rice growing, food supply becomes more abundant and more people can be supported in the same area. Further, in Oriental regions the agricultural system employed in production makes it possible for many persons to find employment in growing the crop. Thus population tends to increase steadily up to the limit of the possibilities of the land to afford food supply and gainful employment for all.

With continuous tenure of definite areas and this increase of population, the people of the rice lands find it desirable to establish an orderly society. Therefore effective social and governmental organizations tend to develop. Further, whereas the migratory hunting, pastoral, and agricultural populations of adjacent areas shift from place to place, with the minimum of responsibility, often without the exertion necessary to make great progress, the tillers of the rice fields are tied to the land. Responsible for the repair of dikes and care of the crop, they soon learn the fundamental lesson that, without the assumption of individual responsibility and the exertion of sustained effort, little advance is possible and that but little more than a bare existence may be expected or can be secured. Thus rice-growing areas became those of greatest development and accompanying cultural advance among the lands of the lower latitudes.

Java: An Example of the Rice Lands. Java affords an excellent illustration of the fact that the growing of rice under an Oriental system of production will furnish support for enormous numbers of people, for the island, smaller than Iowa, likewise predominantly an agricultural area, supports approximately 16 times as many people as does that state whose staple cereal crop is corn, grown with Occidental practices. This is despite the fact that much of Java is mountainous, whereas most of the land of Iowa is arable.

Most of the Javanese live on small farms which average about 2 acres in size, from the production of which they obtain their support; industry and trade are of secondary importance only. In certain of the better parts of the island, a combination of favoring natural conditions makes possible the support of agricultural populations in excess of 1500 and, occasionally, of 1700 persons to the square mile. Few areas in the world, even those which are highly industrialized, support such dense populations, and still fewer, where agriculture is the basis for a livelihood.

Such dense agricultural populations are possible only where necessities are few in number and standards of living are low. In Java, continuously high temperatures decrease food requirements, lessen the amount of clothing necessary, eliminate the need for substantial houses and the use of fuel for heating, all decreasing the costs of living. Even with these favoring conditions, wants must be reduced to the bare essentials, if all are to have their demands met. Therefore the desires of the rice-eaters which can be satisfied are relatively few: food, a limited amount of simple clothing, a house of sorts, and a few other needs of basic importance.

Fortunately, the Javanese are not conscious of suffering any hardship from what we would consider deprivations, strange as this may seem to us; in fact, they are actually a very happy people when their few wants are met. The explanation for this is perhaps to be found in established habits and social customs partially related to climatic conditions which are not conducive to energy, according to Huntington, so that but little thought is given to the fact that fortune might have been more kind. Thus happiness is achieved with what is available. Possibly there may be something to be said for this point of view.

Certainly, life is more leisurely in these warmer areas than in the higher latitudes and time, as we know it, loses its meaning and value. Work, indeed, is for long hours, but not at the pace to which we are accustomed, for what is not done today may be done tomorrow, and tomorrow never comes. Why worry about the day which never arrives? This disregard of the value of time is general, not only in Java, but throughout the rice lands.

Where standards of living become fixed at low levels and food supply is sufficient, or can be increased to satisfy needs by some additional effort, population tends to become dense and to mount until restricted by limitations imposed by the available food supply. These conditions are met in Java, hence the dense and increasing population, 5,000,000 a century ago, but now probably in excess of 48,000,000.

Oriental Agriculture in Japan. The island empire of Japan consists of four large, and many hundreds of small islands, stretching from Cape Satano in southern Kyushu, 31° 1′ North, approximately the latitude of New Orleans, to Cape Soyami in northern Hokkaido, 45° 29′ North, about the latitude of Minneapolis. This is a north-south extent of nearly 1000 miles. Yet, despite the relatively high latitudes in which most of Japan lies, and the great differences in climate from south to north, an Oriental system of agriculture prevails everywhere. This may seem peculiar, unless it is realized that the Japanese were overseas invaders arriving from the south, bringing with them the methods of rice production learned in the areas from which they came.

Originally, the islands were occupied by the Ainu, a population dependent largely on hunting and fishing, and making only limited agricultural use of the land. With the arrival of Japanese in the southern islands, the Ainu were either gradually forced north into the less desirable parts of Hokkaido or they disappeared by assimilation. Today, only a few remain, even in Hokkaido, and these few are segregated in restricted districts.

In the south, where the climate is subtropical in character, and in places so warm that crops can be grown out of doors throughout the year, the introduction of rice as the major cereal crop presented no problem, since many small alluvial plains, as well as the climate, favored production of the crop. Even when its cultivation pushed farther into the main island, Honshu, rice could still be grown without great difficulty, but its northward progress was finally halted by the short frost-free season in Hokkaido. For many years, therefore, the Japanese avoided this northern island, except for its fisheries, for it did not appear to offer opportunity. With its more recent agricultural occupation, the problems arising with attempted use of the land for

FIG. 294. An agricultural scene in late April, on the rice lands of the Ishikari Plain, Hokkaido. In the foreground are the unfenced paddies with piles of rice straw, which will later be plowed under as fertilizer; to the right is the irrigation ditch, paralleled by a typical gravel road; in the background are the snow-covered mountains from which the water for irrigation is secured. The scattered farmhouses are located on the individual farms, which are not fragmented, as they are in the southern islands.

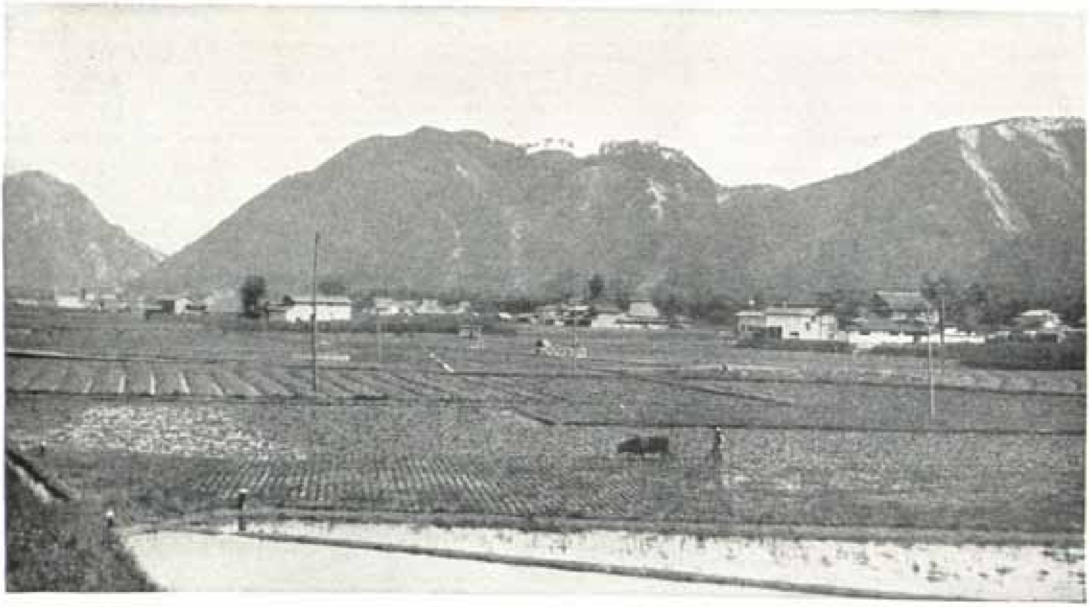

FIG. 295. Typical agricultural scene in the middle of May, on the east coast of southern Honshu, near Hiroshima. In the background are the agricultural villages at the foot of the upland; in the foreground, the flat alluvium where rice is grown. To the left, the paddies have been ridged and winter crops are growing on the elevations, between which water stands. In the foreground, a Japanese farmer, using an ox as a draft animal, is plowing a wet paddy, in preparation for planting rice.

production were so new and formidable to the Japanese that foreign experts from the Western world were brought in to advise as to the best crops and the methods best adapted to their production in this north country, where winters are as long or longer, and the weather is almost if not quite so cold as in southern Minnesota and Wisconsin. Following the advice of these experts, the Japanese introduced some crops, new to their experience, particularly oats. They also eventually succeeded in perfecting a variety of rice that would mature during a 90-day frost-free season, which permitted them to grow their favorite cereal, though somewhat less effectively than farther south, where both the quality of the crop and yields per acre of land in production are better. With all crops grown, however, the practices employed were those of Oriental agriculture, with minor modifications made necessary by the long winters and relatively sparse population. Thus Japan exhibits both types of Oriental agriculture within her borders, as well as the merging of the two systems: (1) that of the rice lands; and (2) that of areas of other small grains and the legumes.

Farm Size and the Pattern of Rural Occupation in Japan. Japan is everywhere a land of small farms, the average farmer working about 2.6 acres of land, or a tract approximately half the size of an average city block. This statement, however, may convey an exaggerated impression of the size of the average landholding in the south, which is increased materially by the larger size of the farms in the northern island, Hokkaido. There, the average rises to over 7 acres, in part because it is a newly settled area and in part because only one crop can be grown each year on a field, in view of the long, cold winters. Thus nearly 70 per cent of all farms are actually smaller than the average of 2.6 acres. In fact, over 25 per cent are only slightly larger than a fair-sized city lot, and owners of as many as 12 acres or more comprise but 1 per cent of all farmers.

The individual farm of the southern islands ordinarily consists of several scattered, unfenced tracts, possibly six in all, each subdivided into a number of small, irregular fields, so that it may include as many as 20 separate subdivisions, each less than half the size of a small city lot. Typically, the farmer of the southern islands lives

in an agricultural village, from which he goes out to work his scattered holdings, about 50 per cent of which are normally rented. In Hokkaido, the northern island, the farmer generally lives on his farm, which is ordinarily not fragmented. With such close agricultural settlement, Japan is a veritable human anthill; in the occupied plains areas where agriculture is possible, even the country literally swarms with people, and all work from sunrise to dark every day of the week, some on the dry upland fields, some in the mud of the rice fields, in an effort to secure a living from the relatively unproductive soil.

Rice in Japan. Japanese agriculture is Oriental in type, with rice everywhere the most important cereal crop, even in most parts of the northern island of Hokkaido, where winters are both long and cold and only one crop a year is possible. In the southern islands, rice is more important than all other cereals combined. In fact, so important is it in the agricultural system that it is grown whenever and wherever possible. Other crops occupy only land which cannot be used for rice, or land which cannot be so used during the winter months. The other food crops such as wheat, barley, rye, buckwheat, potatoes, and others are therefore "filler crops," using land which, either temporarily or permanently, cannot be used to advantage for rice production.

The dominant position rice occupies in the agricultural system of Japan results from a combination of favoring circumstances. First, and of paramount importance, is the fact that the arable land is largely alluvial in character, much of it very flat, low-lying, and permitting flooding without difficulty. Topographically, and with respect of irrigability, such areas are therefore suitable for rice production without expensive preparation. Further, the poorly aerated soils, though satisfactory for use in growing rice, are not suited for ordinary upland cereal crops. In Hokkaido, these soils of the wetter flat land tend to be peats and mucks, likewise capable of producing rice but not well adapted to other crops except

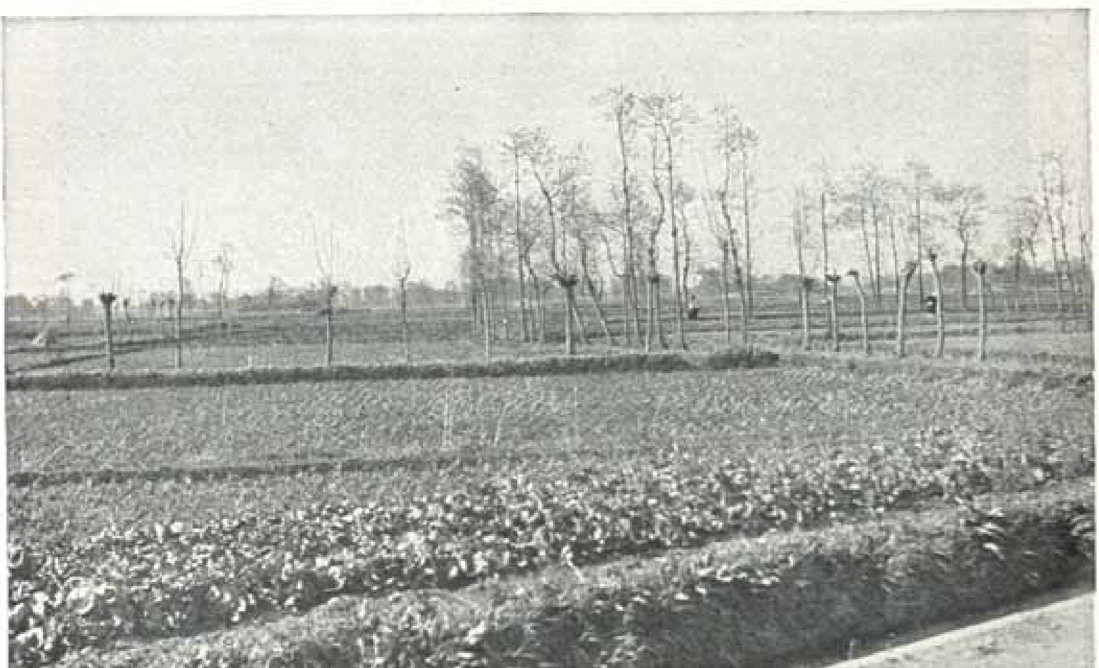

FIG. 296. An agricultural scene in early April, on the Kwanto Plain, north of Tokyo. Here, the paddies, though muddy, are not covered by standing water. Some are in winter crops of vegetables, grown for the Tokyo market; others are idle, but the farmers are already repairing the ridges between them, preparatory to planting time. The trees on the ridges are of no value except that they serve as supports to which poles will later be lashed horizontally. On these, the rice will be hung up to dry, after it has been harvested. It will be noted that the trees have been pollarded, that is, their tops have been cut out, for only the trunks are necessary for use as supports.

FIG. 297. An agricultural scene in eastern Honshu in late May. Winter cereal crops on the higher parts of the alluvial plain are ready for harvest; the flooded rice paddies have not been planted as yet. In the foreground, the road skirts the edge of the upland. The steep slopes of the hills are not in agricultural use and, except as they accommodate houses, are covered with brush and trees. (Courtesy of the Keystone View Company.)

without such extensive drainage and heavy fertilization as to prevent profit.

Second, the yields of rice are high, of late years averaging in excess of 40 bushels per acre. This is one and one-half times the number of bushels of wheat per acre in Japan, and the gain in food values secured by growing rice rather than wheat is even more pronounced, highly important in this densely populated part of the world.

Third, Oriental practices in agriculture, particularly in growing rice, involve much hand labor. This is supplied by the dense population, dependent on and made possible by the crop. This dense population not only makes possible the growing of rice by Oriental methods of pro-

duction, but it ensures as well the necessary employment for the large supply of labor available.

Fourth, rice is a crop which stores well, much better than most crops of the tropics, in fact, almost as well as wheat. The phenomenal keeping qualities of this latter cereal are indicated by the saying, "as good as old wheat in the bin," and by the numerous fantastic stories, none true, that wheat in such good condition that it grew, when planted, has been discovered in the ancient tombs of Egypt. The good keeping qualities of rice are important, for much of southern Japan has warm to hot, humid summers.

Fifth and last, but not necessarily least important, the Japanese like rice. It is, in fact, their preferred cereal food, annual consumption amounting to an average of 5½ bushels per capita. It is very fortunate that they do like this cereal, for it is the only one which can be grown on large areas of the land used for agriculture, for reasons which have been stated previously.

Other Crops in Japan. Some of the arable land of Japan cannot be irrigated to advantage, in which case it is used for growing other cereals: rye, wheat, barley, and buckwheat; other food crops such as white and sweet potatoes, beans, and vegetables; or crops like tea and mulberry. These are all grown, as is rice, by the expenditure of much effort, and yields are high. In the south, where it is warm throughout the year, such crops may be grown at any season, though summer is best; in Hokkaido, where winters are severe, only during the summer. In addition to upland fields devoted to crops other than rice, the paddies in the southern islands, if not too wet, are often ridged and used for food crops other than rice during the winter months. Thus the crops of Japan are the familiar ones of this country and much like those of comparable latitudes elsewhere, but the practices employed in their production are very different from those of the Western world.

Agricultural Practices in Japan. Oriental agriculture, in Japan as elsewhere, involves the expenditure of much labor, but the use of few and simple tools. In the growing of rice, for example, the land is first plowed, then worked over by hand with a mattock. This is done to thoroughly break up the soil and ensure effective incorporation of the organic material, such as rice straw from the previous year's crop, which is spread over the paddy before plowing. Thus, when the field is ready for planting, the wet soil has been reduced to a thick mud of about the consistency of oatmeal porridge. Then the rice plants, grown in seed beds to permit the most effective use of the land, are set out by hand in the field. When the crop matures, it is harvested with sickles and threshed in the farmyard by use of simple homemade devices. All other crops are grown with a similarly great expenditure of labor by men and women alike, for both work in the fields in the rice-growing areas of Japan.

The fields are in continuous use, year after year, and, where climate permits, throughout the year as well. With this procedure, it is possible to grow two, or sometimes even three, crops each year on the same field. This intensive use of the land is made necessary by the fact that the individual farmer may secure not only his food but his entire livelihood from what is really no more than a large garden. Therefore he often practices what is known as "interculture," that is, the growing of two different crops on a field at the same time, planting them at different times so that, when one crop is coming up, the other is maturing. It likewise leads to the use of very poor soils and to the terracing of slopes in order to increase the productive area.

The Japanese farmer is considerably handicapped by the fact that much of the soil of the arable land is inferior to poor and, even where this is not true, continuous cropping of the same fields year after year, and often throughout the year as well, causes a serious drain on the supply of plant nutrients in the soils. Therefore heavy fertilization, necessary to maintain productivity, is the normal practice. In the absence of an animal industry of any importance, especially in the southern islands where agriculture is most intensive and double cropping is common, "night soil" is collected and used to supplement such farm wastes as are available. Each day, the night-soil collector makes his rounds of the houses and inns of the urban centers, and each day a long procession of carts loaded with buckets of this fertilizer wends its way from the cities to the surrounding agricultural areas of the southern islands. Stored in "fertilizer wells" with other wastes, the mixture ferments and "ripens" until such time as it is applied to the crops.

With such practices, it is possible to maintain and even increase soil fertility and to secure very

FIG. 298. A Japanese threshing machine in full swing, Shizuoka, southern Japan. Here, the grain is being beaten out on gratings. In other cases, the head of the rice is drawn through combs, the teeth of which loosen the grain; or, again, a flail may be used. In all cases, threshing is by the use of simple devices. (Courtesy of the Keystone View Company.)

large yields of all crops grown. Thus these often average twice as great as those we obtain on much better soils, used only part of the time. However, it should not be inferred that we ought to imitate these Oriental practices, for the high yields are secured only by an expenditure of so much labor that they are often largely returns on labor rather than from soils. Even in Japan, where human labor is cheap, it is probable that some of the agricultural production is in reality not economic. Further, though every effort is being made to increase agricultural production in Japan, it is conceded to be economically unprofitable to accomplish this by additional expenditure of labor, despite the low wages and low standards of living.

The Animal Industries in Japan. In view of the cheapness of human labor, and because density of the agricultural population forces use of the land to produce the maximum amount of food,

FIG. 299. Buckets of fertilizer on their way to the farm, Kyoto, Japan. At the left, the ox-drawn cart is loaded with "honey buckets"; at the right, the horse-drawn wagon, with bucket in front, has stopped in front of the inn on the corner to secure night soil.

there are relatively few horses or dairy cattle on Japanese farms. This is especially true in the south, where farms are smallest and population pressure on the land is greatest. There, the few cattle that are kept are draft, not dairy animals. In Hokkaido, where population is less dense, farms are larger and much of the arable land is upland which cannot be irrigated effectively. Thus crops other than rice assume greater relative importance in Hokkaido than in the southern islands and animals are more numerous but, even there, they are few in number by our standards. The minor importance of the animal industries everywhere in Japan is indicated by the small annual consumption of animal products, which averages only slightly more than 2 quarts of milk and 3 pounds of meat per capita. This consumption can increase only if the land is freed from the necessity of supporting so many and, as yet, no feasible method of accomplishing this result has been proposed.

Some Problems of Japanese Agriculture. Despite painstaking cultivation and the high yields secured by the Oriental system of agriculture practiced throughout the four main islands of Japan, both the individual farmer and the country are faced with several serious agricultural problems which press for solution. The individual farmer is handicapped by the small size of his farm and its fragmentation. The first limits his total production; the second interferes with efficient cultivation for, even were machinery within his means or available by cooperative purchase, the small size of the fields would prevent its use. Further, not only are the individual farms small, but much of the land, over half of that in rice, is cultivated by tenants and rents are high, 50 per cent of the net yield. Again, the limited amount of land makes it high in price, much of the rice-producing land being held at $1000 or more per acre, which places it out of reach of the average farmer. Thus most of the farmers are poor, and no amount of effort on their part will remedy this condition.

From the standpoint of the country as a whole, it would be desirable to increase the acreage under production in order to ensure more food for the steadily increasing population, but this is virtually impossible, since there are no desirable unoccupied frontier lands in any of the islands.

FIG. 300. Fertilizing sweet potatoes. The buckets, swung from the ends of the pole carried by the woman, contain the fertilizer. One of the men is dipping it from the bucket at the right; the other man is applying a dipperful to the plants. This procedure insures that none of the fertilizer will be wasted. (Courtesy of the Keystone View Company.)

Therefore such additions as are made are almost entirely by drainage of swamps, reclamation of sea bottom, carrying of cultivation farther up the slopes by terracing, and subjugation of active coastal dune areas. The gains from such additions must be small and the costs often too high to be justified. The only other alternatives which will increase total yields are cultivation of varieties which yield better returns, increased use of fertilizer, and expenditure of more labor in production. The last two are not economically feasible; the first may lead to some increase, but the prospect is not very promising. Thus the individual farmer must be satisfied with small and probably decreasing returns, and the country with lack of self-sufficiency in agricultural products.

Population Problems and Agriculture in Japan. For 100 years and more, prior to 1860, the population of Japan remained essentially stationary at 30,000,000 but, since that date, increase has been

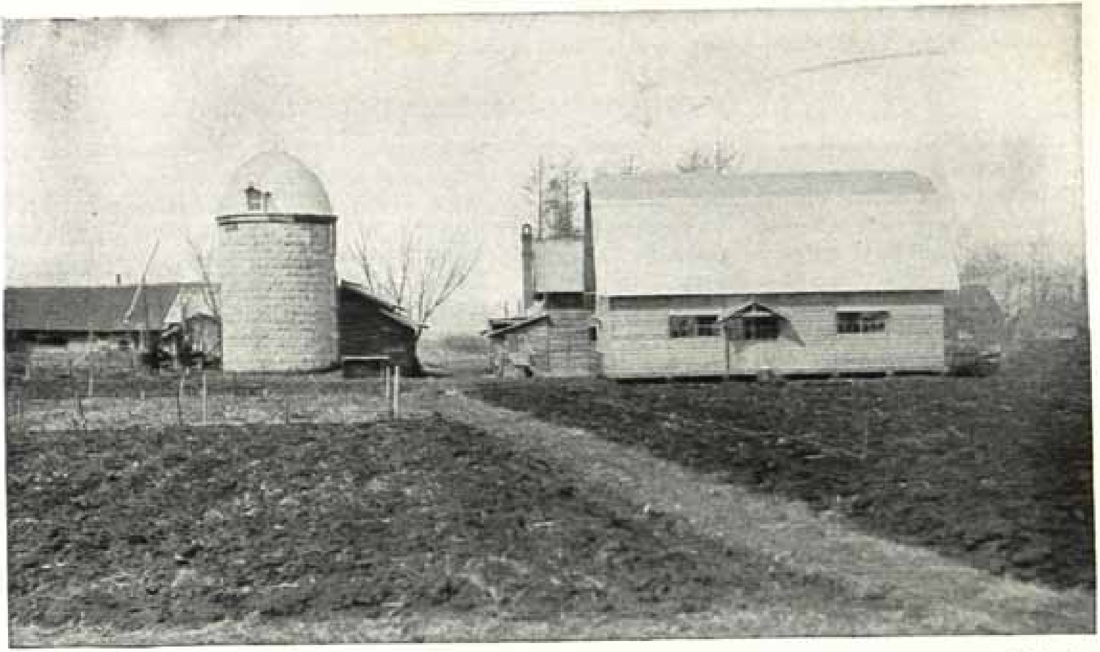

FIG. 301. Rear view of a farmstead on the Ishakari Plain, about 8 miles east of Sapporo, Hokkaido. The greater importance of the animal industries in this northern island is indicated by the barns and the silo. Here, the Oriental type of agriculture and the appearance of the buildings have been modified somewhat by Occidental influence, for the Japanese called in American agricultural experts to advise them as to crops and agricultural practices.

rapid. By 1900, the population had reached 45,000,000; at present, it is approximately 76,000,000, with the present increase at the rate of 900,000 or more each year.

This dense population, largely agricultural, has been made possible by the Oriental type of agriculture practiced, with rice the most important cereal crop. At first, this growth in numbers was not thought to be alarming but rather an evidence of national strength. With a present population of nearly 3000 and an agricultural population of nearly 1400 persons to the square mile of cultivated land, however, it is causing much concern. Further, these densities are the averages for all four islands. In the rice lands of the south, they are even higher, yet each year an additional 900,000 or more persons must be assured a living, largely from the land.

On the basis of an estimated average annual per capita consumption of 5½ bushels of rice, at least 125,000 acres of new land would have to be brought under production each year to provide for all the average increase of population; in practice, the amount added varies from 25,000 to 35,000 acres. This is only enough to care for less than 25 per cent of the population increase. As yet no adequate solution of the problem posed by the rapidly increasing population within the inelastic limits of Japan has been devised, for industrial expansion has not proved sufficient up to the present, and extensive emigration appears to be impossible.

Problems of Other Areas with Oriental Types of Agriculture. These problems are not peculiar to Japan, for other Oriental areas with dense populations suffer at least as acutely. In India, for example, subdivision and fragmentation of landholdings impose the same handicaps as in Japan, intensified by continuous cropping without fertilization and sale of natural manures such as oil seeds. These practices lead to indebtedness and poverty even more serious than in Japan, for it is estimated that one-third or more of the farmers are hopelessly in debt, and only about one-fifth are free from indebtedness. This compels maximum immediate production, irrespective of its desirability, which ensures continuance of low yields and poverty, and the necessity for securing

maximum yields at all times to escape actual starvation. Thus India, like Japan, and even Java, has its agricultural problems, for which no solution is now in sight.

QUESTIONS AND EXERCISES

1. How does agricultural use of the land operate to modify the natural environment?
2. In what two centers did sedentary agriculture probably originate? Where are the present agricultural frontiers of the world located?
3. What factors determine the character of the advance of agriculture along the agricultural frontier? How does each operate?
4. What are the two major types of sedentary agriculture? Describe the characteristics of Oriental agriculture. What are its two subtypes? In what country do both occur?
5. What fraction of the earth's land surface do the rice lands occupy? What is their population? How is such a great density of population possible? Why is rice an excellent crop for such areas?
6. Describe the physical conditions of the lands suited to rice production and state the advantages such areas offer for cultivation.
7. Where is rice supposed to have been native? Describe the spread of rice production from this center.
8. Why did the rice-growing areas of the Orient develop stable social organizations at an early date? Contrast this development with that of a migratory agricultural population such as the Fang.
9. Describe the agriculture, population density, and the standards of living in Java.
10. Why are the Javanese satisfied with these standards of living which seem so low to us?
11. What establishes the limits of population densities in the rice lands? Illustrate by Java.
12. Who were the original inhabitants of Japan? How did they make a living? Where may they be found today? From where did the Japanese come? How does this explain certain aspects of their agriculture? How did these handicap occupation of Hokkaido?
13. What is the size of Japanese farms? In the south? In the north? Why are they larger in the north? How do landholdings and the place of residence of the farmers differ in the north and south of the four main islands of Japan?
14. How important is rice among the crops of Japan? What position do the other crops occupy in the agricultural system?
15. Why does rice occupy such a prominent position among the crops of Japan?
16. What crops, other than rice, are raised in Japan and where are they grown?
17. Describe agricultural practices in Japan, particularly those of the rice-growing areas. What is meant by interculture? By terracing?
18. Why is heavy fertilization of soils necessary in Japanese agricultural use of the land? What is used as fertilizer? Are all Japanese agricultural practices justified and, if not, why?
19. What is the importance of the animal industries in Japan? In what parts of the country are they most important? Why? What is the average annual consumption of such animal products as milk and meat in Japan? How does this indicate the small importance of the animal industries?
20. State the problems of Japanese agriculture.
21. What is the present population of Japan? What was the earlier population? When did marked increase of population begin? What is the present rate of increase? How does this present a problem? What solution would you suggest for this problem?
22. Is agriculture prosperous in India? How does this condition result from agricultural practices? How do these tend to perpetuate present conditions? What solution would you suggest?

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Chapter Thirty-Two

OCCIDENTAL AGRICULTURE: INTERMEDIATE LATITUDES

The Agricultural and Other Stages of Man's Development. Present-day man has evolved through the collecting, hunting, pastoral, and agricultural stages of development to a fourth, the industrial. But, though *Man* has passed through all of them, this is not true for individual population groups, for there are still migratory hunting and nomadic pastoral populations, as well as those in the sedentary agricultural and industrial stages of development.

Among those groups today supported by hunting and nomadic herding, there has generally been some domestication of animals, but little or none of wild plant life, as has been noted earlier for migratory hunters such as the Eskimo and Bushman; and for the Lapps, Kirghiz, and other pastoral nomads. This was probably true as well for other migratory populations in the far-distant past, long before the existence of any written record. The domestication of animals and the growing of grains, moreover, probably had their origins in different areas, whose inhabitants obtained their livelihoods in quite different ways. Certainly, though a nomadic life may permit or even favor the domestication of animals, it does not encourage cultivation. Therefore it is likely that the earliest grain growers were peaceful "collecting" people, possibly living in village groups for mutual protection against marauding nomads, as some similar populations do today in certain parts of the world.

The Origin and Characteristics of Early Occidental Agriculture. The exact place of origin of the practice of agriculture still remains a subject of speculation and inquiry, but enough facts are known to make it relatively certain that the Occidental systems and practices trace their beginnings to developments which occurred at the eastern end of the Mediterranean, in an area lying between the lower Nile Valley and that of the Tigris-Euphrates. From this center, they spread both east and west. To the east, they had only a limited influence on the agriculture of the Indus Valley and beyond; to the west, they had a marked effect on that of the Western world.

It may well be that, as suggested earlier, the first plantings of grain by collecting populations were accidental, though these later led to purposeful sowings to obtain a source of food to supplement the scanty, uncertain, and often decreasing supply afforded by wild growths. The use of domesticated animals for cultivation of such crops was a still later development, the animals used being a contribution of the steppe grasslands. With development of sedentary agriculture, patron divinities to whom the people paid homage and tribute, in the hope of securing satisfactory returns for their labors, were set up in those areas where such agriculture afforded the basis for support, for example, in Egypt and Greece, to the plains of which the growing of bread grains had spread at least as early as 2500 B.C. Thus the Egyptians prayed to Isis, whose tears were believed to cause the floods of the Nile which made agriculture possible; the Greeks, to Ceres, the goddess of growing vegetation, from whose name is derived the term "cereal," meaning grain. Some of the preceding statements are based on rather limited data, it is true, but their probability is undeniable, and such facts as are available substantiate them.

The Spread and Development of Occidental Types of Agriculture. With the spread of Occidental agriculture from the relatively warm areas with light rainfall and a winter maximum of precipitation at the eastern end of the Mediter-

ranean to western and northwestern Europe, eventually from there to the Americas and other lands of middle latitudes, and, of late, into the lower latitudes as well, certain adjustments and modifications of earlier practices have developed. These have been made possible and desirable by the introduction of new crops and by new demands.

Grain growing was probably man's first venture in agricultural production, and the first grain grown was almost certainly either a "wheat" or barley, for the wild ancestors of both barley and wheatlike grains are known at the eastern end of the Mediterranean, where Occidental agriculture had its origin, though the derivation of our modern bread wheats is more obscure. As agriculture pushed into the cooler and better watered regions to the north, oats were added to the list of cereal crops, wild oats, which have a wide distribution across Eurasia, being thought to have been first grown as a cultivated crop in the early Christian era by Teutonic tribes in north Germany. Two other cereals, rye and buckwheat, were also contributions of some importance from these same cooler areas. With discovery of the Americas, still another cereal crop, maize or "corn," was added to the list. Much later, some of the grain sorghums such as feterita, milo maize, and Kafir corn were imported from Africa, but the total effect of their introduction was slight, for they are grown on only limited acreages and only in restricted areas. Rice, introduced from southeastern Asia at an early date, is likewise of relatively slight importance as a crop in the Occidental world, except locally.

In addition to the grains which became known with extension of the areas explored and settled by white populations, the Americas contributed two other important crops: potatoes and tobacco. The former is grown extensively today in widely scattered regions, in some of which it has worked a revolution in agriculture; the latter, though widely used, in more restricted areas and on much smaller acreages, in part because of the requirements of the crop. In similar fashion, the Orient contributed the soy bean, which promises to play a much more important part in our agricultural economy in the future than it has in the past, as well as silk, which has never become of great importance because of the competition of Oriental production.

The crops listed are not all that have been added as an accompaniment of increased knowledge of the earth's land surface and the extension of Occidental agriculture into new areas, but only the more important. Further, the list grows in length yearly, for agricultural explorers are combing distant regions with the hope of discovering still others which will fit into our agricultural systems to advantage. Again, new and improved varieties of the older crops: some maturing in a shorter frost-free season; some giving better yields; some yields of better quality; some more disease resistant; and some possessing still other desirable characteristics are being perfected yearly, so that modification of our agriculture may be expected to continue for an indefinite period of time. It is this lengthening list of crops, from which the individual farmer is free to make an effective choice within limits imposed by the environment; the expansion of Occidental agriculture into new regions with different possibilities; and the development of more adequate transportation systems, agricultural machinery, and other technical advances which have led to the great diversity of agriculture and agricultural practices in the Western world.

With expansion of sedentary agriculture to the northwest in Europe, changed climatic conditions which improved pasturage, the addition of new crops including those useful for fodder, and the necessity for winter feeding led to the use of cattle not only as beasts of burden and plow animals, but to supply dairy products and meat. Swine, indigenous to these timbered areas, were likewise raised, often in the forest in a half-wild state, to furnish part of the local meat supply. With this greater emphasis on livestock, much of the farm activity centered around the animal industries in this part of Europe. The same condition obtains today in parts of the United States, Canada, and other areas in intermediate latitudes where pastures are good or the crop system favors production of animals and animal products.

The Pattern of Early Agricultural Occupation of Western Europe. In the previous speculations as to the origin of grain farming, it was stated that it probably developed around settlements of sedentary or semisedentary collecting populations rather than among migratory hunters or nomadic herders. For long thereafter, also, farmers lived in compact settlements, located near their tilled fields. Thus, during the Middle Ages,

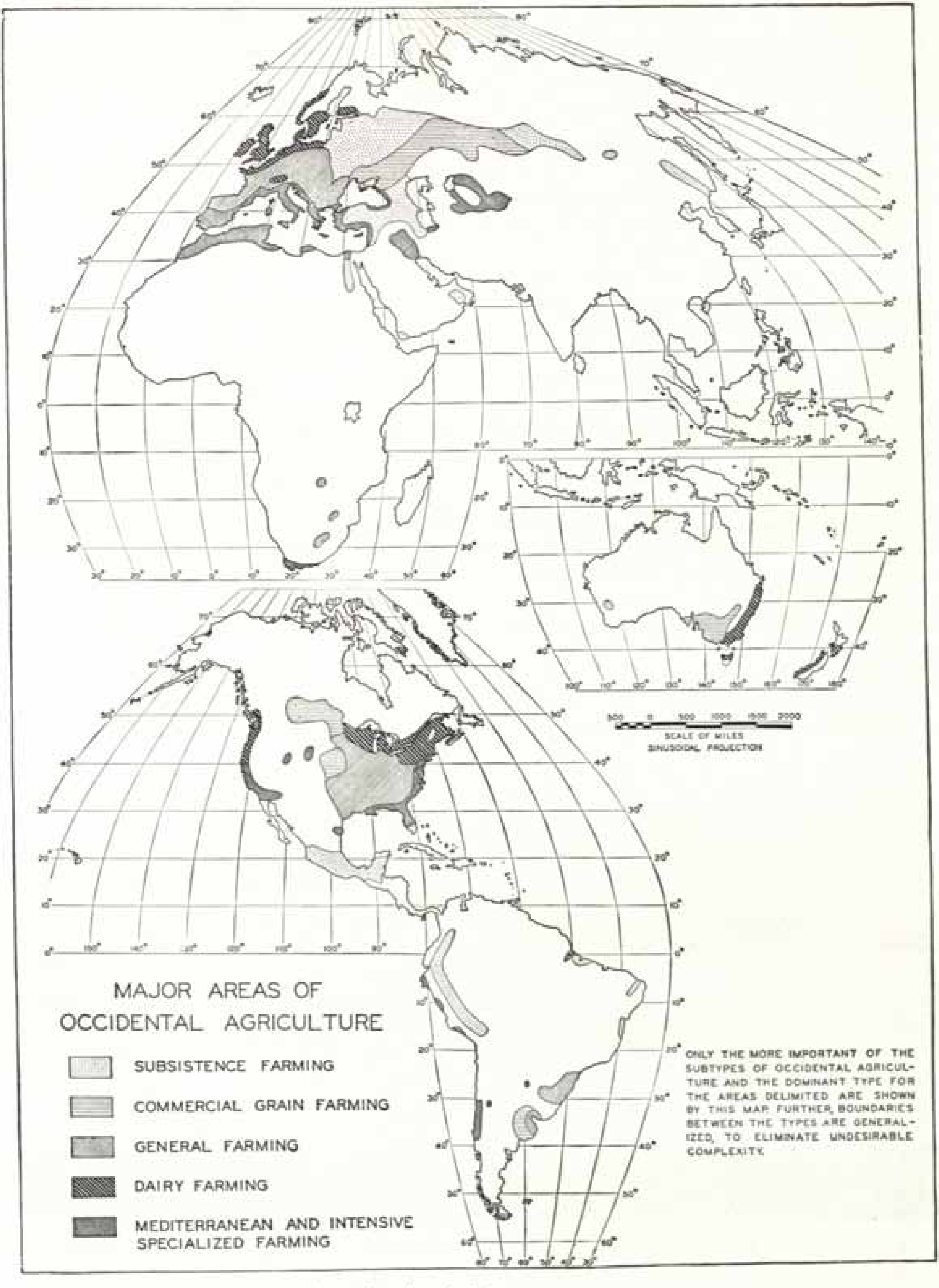

Fig. 302. Distribution of types of Occidental agriculture.

the farmers of much of western Europe lived in self-contained agricultural villages, meeting their own food requirements. Only in years of exceptional harvests did they have a surplus for sale; quite as often, indeed, they suffered from shortages or even famine conditions.

In such villages in England, the arable fields were worked in parcels by individuals, all sharing alike in good and poor land. Both the meadow or grassland and the cultivated fields from which the crops had been removed were used as common pasture for the village animals. Since it was necessary to produce the food consumed by the inhabitants of each village on its own fields, freedom of choice as to fields to be plowed and crops to be grown by the individual peasant was considerably restricted, to ensure the common good. Further, to prevent decreasing productivity of the arable land, each individual farmer allowed either one-third or one-half of his cropped land to lie fallow each year, in the absence of adequate amounts of animal manure. In many respects, therefore, these villages were cooperative units, in which the landholdings were administered for the good of all.

Living conditions in these early agricultural villages were very primitive. The inhabitants lived in clay or wattled huts with thatched roofs and no chimneys, so the interiors were often smoky and always smoke-blackened. Floors were of dirt, furnishings were few and crude, living conditions were hard, and life expectancy was low.

These villages, at first relatively few in number, were the nuclei from which agricultural settlement spread into bordering forest and waste areas, as population increased. During the Roman period, for example, much of Gaul was wild woodland, with the agricultural villages widely scattered; its transformation into cultivated fields and its present agricultural use did not begin in an important way until the middle of the eleventh century, when village populations began to invade the forest margins. Even at that time, conquest of the forests, marshes, and swamps was difficult at the then-existing stage of man's development, when technological advance had been slight and a hostile environment was therefore a great deterrent to his occupation of an area.

Types of Occidental Agriculture. Addition of new crops to those grown during the earliest stages of the development of Occidental agriculture, particularly those contributed by the Americas, introduced new possibilities in crop combinations, and the perfection of new varieties multiplied their number. Further, as producing areas

FIG. 303. A herd of Hereford yearlings feeding on Sudan grass pasture in Cass County, eastern Nebraska. Note the height of the grass, an importation from Africa. These are beef cattle, shipped from the short-grass country to the west, an area of commercial grazing, to be fattened for market. When prices for fattened steers are favorable, such feeding of range cattle affords a profitable use of crops grown in this area of general farming. (Courtesy of the U. S. Soil Conservation Service.)

spread, transportation improved, and urban development increased, markets expanded and specialization of production displaced the older practices of self-sufficiency to the extent that today there are several well-developed types of Occidental agriculture. In our consideration, we shall recognize two major divisions: (I) Occidental agriculture of intermediate latitudes, which will be discussed in some detail in this chapter; and (II) Occidental agriculture of the tropics, a relatively recent development, largely of the plantation type. This second division, Occidental agriculture of the tropics, will be considered in the chapter which follows. For purposes of discussion, the first of these two major types of Occidental agriculture, that of intermediate latitudes, will be subdivided into: (1) subsistence agriculture; and (2) commercial production, of which the following four subtypes will be recognized: (*a*) general farming; (*b*) commercial grain farming, including dry farming; (*c*) dairying; and (*d*) intensive and specialized farming, both with and without irrigation. In outline form, this classification is as follows:

I. Occidental agriculture of intermediate latitudes:
   1. Subsistence agriculture
   2. Commercial production:
      a. General farming
      b. Commercial grain farming, including dry farming
      c. Dairying
      d. Intensive and specialized farming, both with and without irrigation

II. Occidental agriculture of the tropics.

It should be realized that these classes of farming are not necessarily mutually exclusive and, as well, that a more extended subdivision would, despite the disadvantage of increased complexity, permit a more exact assignment of certain farming systems to the class of operation in which they fall.

Subsistence Agriculture. Until markets for surpluses exist, and the possibility of supplying needs not satisfied by local production are available, a self-sufficing or subsistence type of agriculture must be practiced. This, then, was the type common everywhere for many centuries; it was the type practiced by the early American pioneer; it still persists in a few areas. With our present transportation system, however, and with many large urban centers in which surpluses may be sold, this type of agriculture has already disappeared from most parts of the world occupied by white populations. Only in relatively inaccessible regions such as parts of the Ozarks, some portions of the dissected Allegheny-Cumberland Plateau, limited tracts of other rough country in southeastern United States, and in comparable areas in Europe and elsewhere does this type of agriculture persist. Even there, older agricultural practices, as well as other survivals from earlier periods of history, are undergoing modification as isolation disappears.

In areas such as the Kentucky and Tennessee Mountains, a portion of the Allegheny-Cumberland Plateau characterized by a subsistence type of agriculture, cultivation is generally careless and frequently unwise. In past times, the fields were often prepared for planting by being "drug" with a branch, for many of the farmers did not own plows. Such primitive, shallow cultivation is undesirable. Further, when the forest cover of the steeper slopes is removed and the soil disturbed by agricultural use, excessive erosion occurs; the hillside fields are stripped of soil; and the formerly productive adjoining flat land is covered with sterile sand and loose rock. This unfortunate result is facilitated by the fact that the major and often the only crop, corn, contributes but little to holding the soil in place, so that the life of many hillside fields under cultivation does not exceed 5 years. Thus in the Kentucky and Tennessee Mountains, an area of early settlement, much of the land has already passed out of production permanently and support of the present inhabitants by agriculture becomes increasingly difficult, for populations are often denser on the productive land than in many parts of the corn belt. Where subsistence agriculture is practiced in European areas, corn is likewise often the dominant cereal crop, though it is frequently displaced by other cereals on moderate slopes and valley floors. There, as well, populations are often dense on the limited areas of arable land, and standards of living are low.

The animal industries associated with the subsistence type of agriculture are generally of slight importance. A few cattle and sheep and, in Europe, goats as well, may pick up a living in the open forest, but the most important animals are often swine. This is both an old and primitive type of animal industry. It supported the swineherds of northwestern Europe during the Medie-

val period and earlier for, even in Biblical times, the "husks," mentioned in the Old Testament as affording food for swine, were not those of cultivated crops, but the pods of the bean-bearing carob tree.

Such farming of poor land does not produce a salable surplus. In densely populated areas, in fact, it may even fail to yield an adequate food supply for the inhabitants, so that malnutrition and accompanying disease cause deterioration of the population stock. Further, once firmly established, the system tends to be self-perpetuating, for poverty makes necessary the maximum possible returns which, in turn, accentuates the undesirable conditions which make the immediate return of paramount importance.

The subsistence type of agriculture, still practiced in limited areas with topographic and living conditions such as those shown in Figs. 9, 10, 33,200, and 201, passes by imperceptible stages into general farming, in which crops are diverse, the animal industries normally of considerable importance, and surpluses of both crops and animal products are sold.

General Farming. General farming in the United States, with its associated animal industries, developed from transfer of crops and practices of the forested areas of western and northwestern Europe to the Americas. When first instituted, it was essentially the earlier subsistence type of farming of northern Europeans. Except in limited, isolated areas, however, these earlier practices have been modified materially or displaced completely with introduction of new crops, particularly corn, development of new varieties of those of longer cultivation, and improved marketing facilities.

In those areas where general farming is practiced, farms are ordinarily of moderate size, and a considerable variety of crops is commonly grown. Included in this list are the cereals: corn, oats, wheat, barley, rye, and buckwheat. Of these, corn is most important, for it is grown wherever climatic conditions permit. Where these are satisfactory, corn can be grown to advantage on acreages limited for the most part only by market conditions, the desirability of distributing the farm work, and particularly by the necessity of a crop rotation or a change of crops to ensure continued soil productivity or, in the language of

Fig. 304. Harvesting Burley tobacco, Fayette County, central Kentucky. At the right, the plants are still undisturbed; at the left, they have been cut and inverted on stakes to wilt. Later, they will be hauled to the tobacco barn in the background for curing. After curing, the crop will be marketed by auction on the "tobacco floors" of Lexington. In this area, tobacco is grown in rotation with other crops: corn and bluegrass, tobacco following bluegrass sod. The animal industries are likewise important in this part of Kentucky.

the farmer, to prevent the land from being "corned to death." Of the other cereals, oats rank high in importance, furnishing both food for the farm animals and a satisfactory crop to be grown as part of a rotation. Wheat, barley, rye, and buckwheat, and occasionally some other cereal as well, are likewise important in many general farming areas, sometimes as part of the crop rotation and sometimes as soils or local market conditions may induce their production. Part of the cultivated acreage is also normally used for growing potatoes, root, and hay crops, and sometimes for soy beans, either cut for hay or grown for the beans. All of these may be either cash or fodder crops. In addition, part of the land, generally that less well adapted to cultivation, is left in permanent or semipermanent pasture, which may be fertilized; and some in farm woodlots, which may serve as windbreaks, supply fuel, or even some lumber for use on the farm. Again, there is often some production of fruit and vegetables, principally for home use, and a cash crop such as tobacco may be grown on part of the land under cultivation.

In areas of general farming, however, most of the crops produced are not sold, but fed to the animals: cattle, hogs, poultry, and sometimes sheep. For this reason, the economic activities of the farm tend to center around the animal industries, which furnish an opportunity to market most of the crops in the form of animal products: meat, milk, and eggs. Often, indeed, especially in the transition stages to other types of agriculture, especially dairy farming, the emphasis on the animal industries becomes so great that feed is purchased to supplement that produced on the farm.

General or diversified farming is one of the more important of the Occidental types of agriculture of intermediate latitudes, for it supplies much of our food, especially that derived from animals, as well as some of the raw materials used by industry. On their warmer margins, areas where this type of agriculture is practiced merge gradually into others with more specialized production, sometimes of a semiplantation type; on their drier, cool borders, into areas of commercial grain farming; on their cooler, well-watered sides, into those of dairy farming. These are, of course, statements of general relations and therefore subject to local exceptions. Within their borders, moreover, certain limited areas are characterized by special types of production which set them apart.

Thus, not only is there diversity of production in areas of diversified agriculture, but likewise considerable variation within the general area where diversification is the common practice. Despite this variation from area to area, and even in any given area or on a single farm from year to year, the general pattern of production is relatively constant over regions of considerable extent, with local or temporary departures ordinarily reflecting current market possibilities, influenced particularly of late by governmental policies; and individual choice of the farmers, based on conceived opportunity. In addition to variations induced by these factors, favoring local conditions may lead to emphasis of some "money" crop. Thus in the Kentucky Bluegrass, where many crops are grown and the animal industries are of great importance as well, Burley tobacco, an air-cured type used in the manufacture of cigarettes, assumes importance as part of the crop rotation and as a cash crop.

Diversification of agriculture is highly desirable wherever it is economically possible, for it tends to maintain soil productivity unimpaired if practiced intelligently, since it involves use of any given field for a sequence of crops rather than for a single crop, year after year. Further, in association with the animal industries, there is a return to the soil of much of what is removed in the form of crops; if feed is purchased, the soils may even increase in productivity under use. In addition, by spreading the work, for the several crops grown need attention at different times, it enables the farmer to utilize his time to good advantage and to keep himself occupied for a large fraction of the year, especially if the animal industries assume considerable importance. Despite this desirability, however, it is well to remember that such diversification of agriculture can be effected only where natural and other conditions are favorable, and that it is impracticable in many areas, at least for the present.

As has been mentioned earlier, this type of agricultural use of the land, general farming, is associated with farms of moderate size, which makes for fair densities of farm population and a relatively compact pattern of settlement, as shown in Fig. 20. With high productivity assured by this agricultural system, land prices

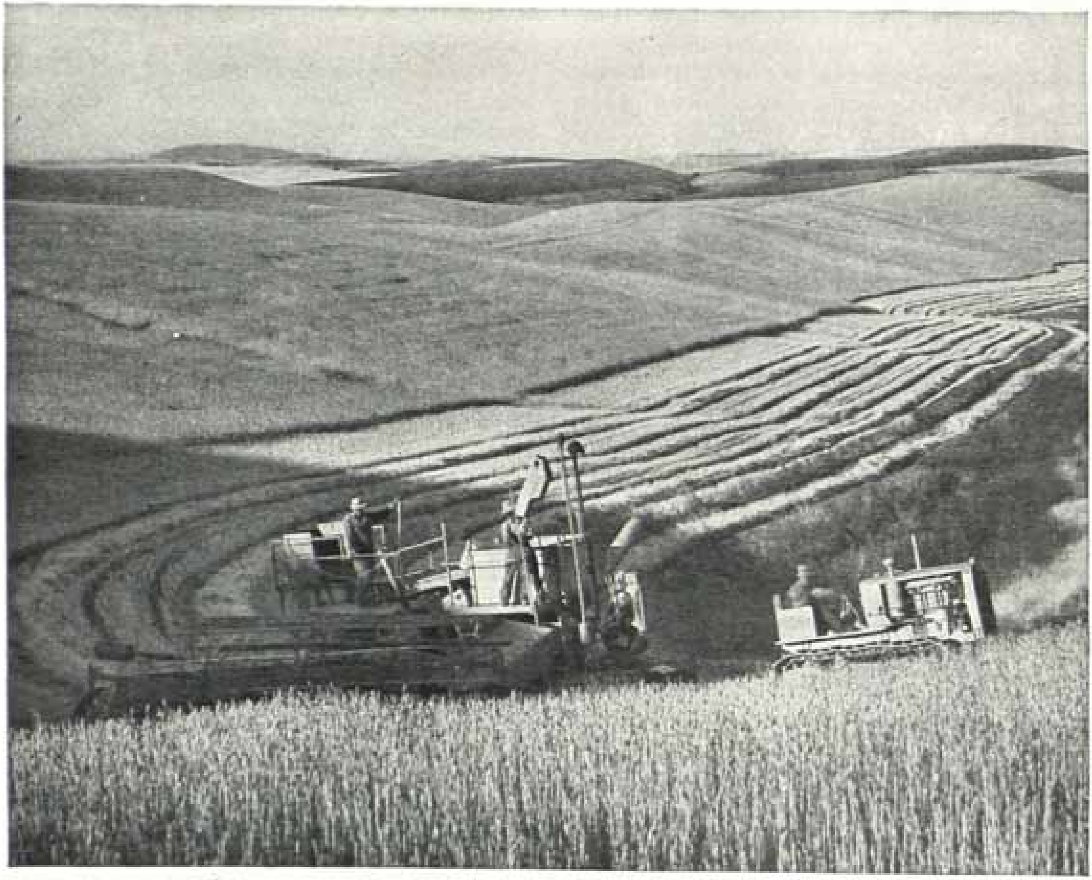

FIG. 305. Harvesting wheat in the Palouse Hills near Pullman, eastern Washington, with use of a Diesel caterpillar tractor and a combine. With this outfit, it is possible to harvest 50 acres of wheat in a 10-hour day, a large acreage for such a short time. Sometimes the combines are operated continuously, both day and night, with use of floodlights and shifts of workers. Eastern Washington is one of the great wheat-growing areas of the United States, for it is favored by both climate and productive, moisture-retentive loessal soils, as well as by topography. In few if any parts of the world is agriculture more extensive or highly mechanized for, on the large farms and with the type of farming practiced, extensive use of machinery is profitable. (Courtesy of the Washington State Progress Commission.)

are relatively stable and high enough to permit maintenance of the necessary community services, including good roads and schools. In such agricultural communities, small towns which, considering their size, do a surprisingly large amount of business, are spaced regularly at intervals of a few miles, so that near-by markets are assured. These are all conditions which add to the attraction of farm life in areas of general farming or diversified agriculture.

Commercial Grain Farming. This type of agriculture, with production of bread grains its major objective, and the animal industries of slight if any importance, is characteristic of the better watered steppe grasslands of the Americas and Eurasia. In a few localities, commercial grain farming also invades both irrigated areas and regions of greater rainfall, where either specialized production or diversification of agriculture is the general practice. Where this occurs, however, landholdings are normally moderate in size, and industrial or other markets create unusual, favoring conditions or, in irrigated areas, markets are not available for the products of more specialized and profitable use of the land. Similarly, commercial grain farming penetrates the predominantly grazing areas in places, either temporarily or permanently, though returns from

such use of the land may be so uncertain as to introduce an unwarranted gamble into agriculture. This production is made possible only by special dry-farming practices.

Where such practices are followed, as in the drier parts of the Great Plains and in the Columbia and Snake River basins in the United States, summer fallowing is usual. This means that fields are clean cultivated or fallowed, normally in alternate years, ordinarily producing a crop of grain only once in two successive years. This permits use of the rainfall of more than one year for producing a crop. Where summer fallowing is practiced, fields are plowed early in the spring, then harrowed and cultivated during the summer to prevent growth of volunteer grains and weeds and loss of water by evaporation from the soil. Sometimes the land is also plowed again in the fall, and the soil is loosened to a total depth of as much as 16 inches to permit effective absorption of water. Such a considerable amount of cultivation to grow one crop necessitates extensive use of power machinery on large landholdings to reduce costs; otherwise the generally low yields secured would destroy all possibility of a profit.

Such dry farming is speculative in character at best for, in addition to the normal hazards of agriculture in better watered regions, great uncertainty as to yields is introduced by marked variation in annual rainfall. (See Fig. 97.) Where carried on unwisely, or without due regard for the limitations imposed by the small amount and irregular distribution of the rainfall, attempted use of the drier lands for growing crops produces disastrous effects which bankrupt the farmers and cause much farm abandonment. Where actual desertion of the land does not occur, a large fraction of the population may need financial assistance in the form of feed and seed loans, or relief not disguised as a loan. Further, when the unplanted soils dry out, they drift before strong winds, so that their future value for agricultural use is impaired or even destroyed completely. When this occurs, attempted use of the land for growing crops has accomplished only destruction of the possibility of its use for the profitable grazing of livestock.

The core of the area of extensive commercial grain farming, then, is confined to the better watered steppe grasslands lying between areas where greater rainfall makes diversification of

Fig. 306. Wheat threshing scene on the steppe grasslands of southern Alberta, Canada, about 35 miles south of Calgary. Here, topography favors the use of machinery, and climate, wheat production, for the rainfall of 16.2 inches, though too small for corn, is ample for wheat, especially in view of the relatively high latitude and the low rate of evaporation, plus the fact that nearly 80 per cent of the total amount of precipitation falls from May to August inclusive. Farms are large and houses widely spaced in this part of Canada. Shade trees are few in number and difficult to grow because of the light rainfall. Therefore, to one accustomed to better watered areas, the landscape may appear somewhat barren. (Courtesy of the Canadian Pacific Railway.)

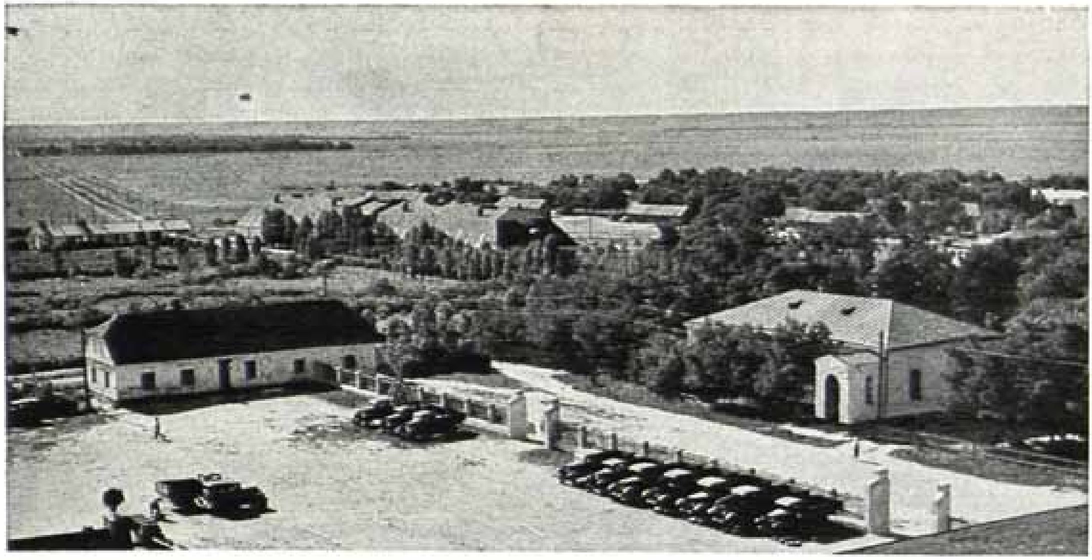

FIG. 307. The Kuban State Farm, in the "North Caucasus." On this "million acre" farm of the U.S.S.R., the workers live in compact settlements. One of these villages is shown in the foreground; a second in the distance to the left; still others, more indistinctly, in the extreme background. On this farm, power machinery is used extensively: tractors; combines; tractor plows, drills, and mowers; and trucks, several of which are shown above. In this area, topography and climate make mechanization of agriculture both possible and desirable. (Courtesy of Sovfoto.)

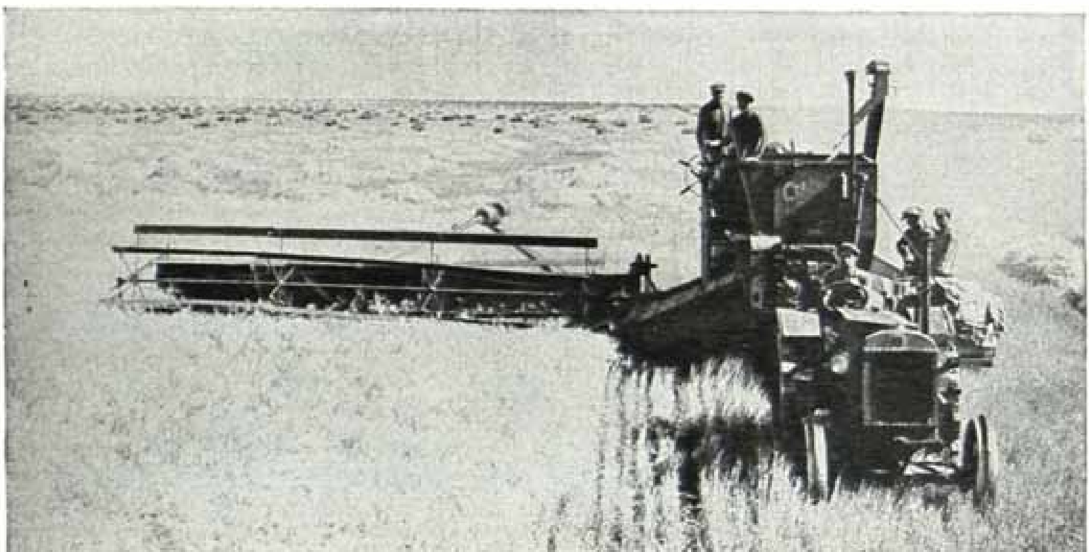

FIG. 308. Harvesting winter wheat with a "Stalinets" combine in 1937 on the Sower Collective Farm, in the Azov or Black Sea area, U.S.S.R. Here, relief favors use of power machinery and, a combination of other natural conditions, the growing of winter wheat and high yields per acre, reported as "nearly 25 bushels in 1937." (Courtesy of Sovfoto.)

agriculture the rule and the drier steppe grasslands, where use of the land for grazing dominates.

In the major areas of commercial grain farming, climate eliminates the profitable growing of corn, except in a few localities, and, even there, acreages are small and much of the production is for silage; but it favors the growth of small grains, particularly wheat and barley, with the former usually the more important of the two. Where winters are not too long and cold, the wheat, known as "winter wheat," is fall sown; elsewhere, "spring wheat," so called because it is spring planted, is grown. In addition to wheat and barley, some oats and rye are raised, the relative importance of these two grains varying with locality and standards of living. Flax is likewise a crop of local importance, and certain of the grain sorghums are sometimes grown where conditions are favorable.

Wherever this type of agriculture, commercial grain growing, is characteristically developed, landholdings are large and mechanization is extensive, for only under such conditions is profitable agriculture possible. In no other type of land use for growing crops in intermediate latitudes, indeed, is agriculture so extensive and the use of farm machinery so important as in commercial grain farming. With this use of machinery, costs of production fall so low that a profit is possible even with small yields, sometimes well under 10 bushels of grain per acre. In fact, it is only with a high degree of mechanization that use of these submarginal agricultural lands for growing crops is possible for, with ordinary methods of cultivation, returns would be inadequate. Thus, in China, with its Oriental system of agriculture, similar lands are still grazed rather than cropped, though the great need for additional food would suggest that they should be put to more effective use.

This type of agricultural use of the land became possible only with perfection of labor-saving machinery, and the use of such machinery became feasible only when agriculture invaded the grasslands, particularly those of the steppes, with their favorable topography, productive soils, and cheap land. For many years the typical form of use of such lands in the United States, these practices have of late invaded Eurasia in the "collectives" of the U.S.S.R. There, they have not only become established west of the Urals, but they have also invaded the Asiatic steppes, including the domain of pastoral nomads such as the Kirghiz, as has been noted earlier, so that where formerly only flocks and herds grazed, today combines harvest grain on state-operated farms of enormous extent.

In commercial grain farming, the objective is production of a surplus for sale rather than achievement of even approximate self-sufficiency. Therefore dependence for most items of the food supply is upon other areas better suited to their production. This is particularly true in the United States, though to a lesser extent in the U.S.S.R., where the workers who till the soil of the collectively operated fields have small parcels of land of from ½ to 1 or more acres which they cultivate for their own use, and on which they may keep a few animals.

In general, the regions of extensive small grain growing tend to expand into drier areas, with accompanying preemption of their more promising portions by more intensive types of agricultural use, made possible by the perfection of new, more drought-resistant varieties of crops, and development of improved agricultural techniques. Further, their boundaries are subject to fluctuation. During a series of wetter years, for example, advance into drier areas becomes possible and occurs; during drought years, retreat sets in. Therefore the agricultural frontier shifts steadily, though it is generally conceded that the limit of desirable advance has already been reached or even passed in most parts of the world. It should be borne in mind that much commercial grain farming in these drier areas is highly speculative, and that some of it is not justified, for destruction of the range without accompanying success in agriculture produces results of negative value, not only for the individual, but for society as well.

In commercial grain-farming regions in the United States, settlement is widely dispersed (see Fig. 20), and the same is true for other areas in this type of use elsewhere in the Americas. Each farmer lives on his own farm, though sometimes only during the summer months, and houses are far apart. This makes for considerable isolation of the individual family, limited social contacts, and the relatively sparse permanent population results in wide spacing of urban aggregations, most of which are small. Further, the local community services, such as schools, must

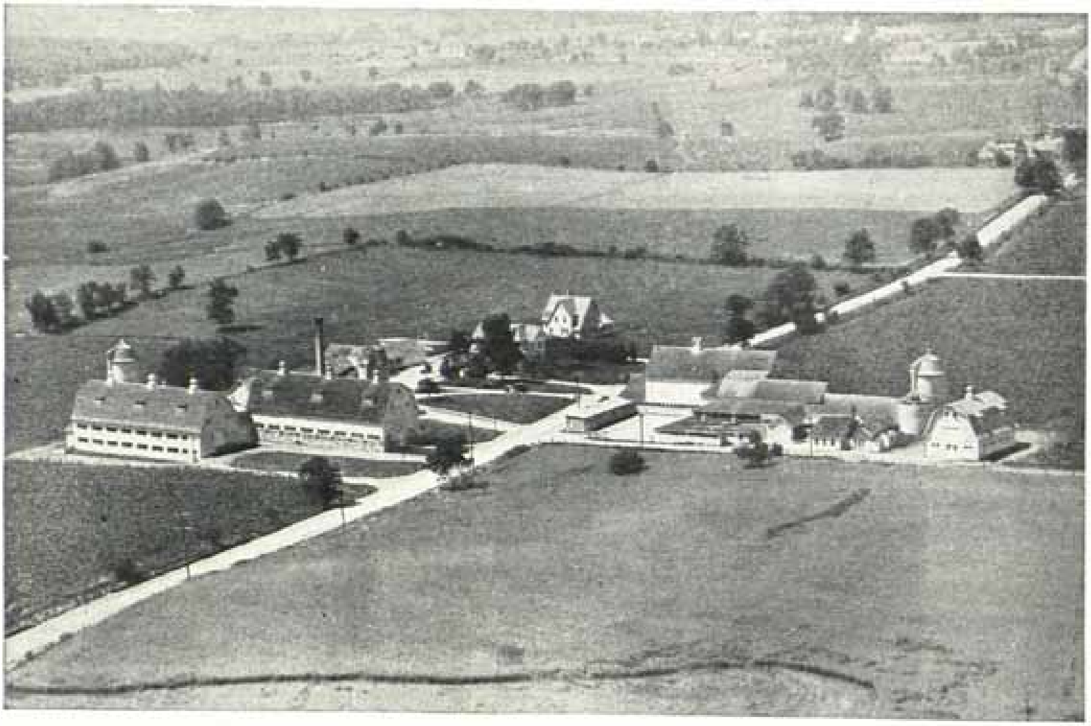

FIG. 309. A south-central Wisconsin, Waukesha County, dairy farm, which supplies the Milwaukee market with scientifically handled milk. In this area, farms are of moderate size, averaging slightly less than 120 acres, and there is much use of laborsaving machinery. Farmhouses are scattered, but relatively close together, as may be noted in the illustration. Rural-farm population is of moderate density, for Waukesha County, 27.7 persons to the square mile. This is nearly three times the average for the United States as a whole, but this is a much better than average agricultural area, with good access to markets. Further, this is a much better than average dairy farm in this particular area. More nearly average conditions are shown by Fig. 187, together with a typical southern Wisconsin dairy herd. (Courtesy of the Wisconsin Department of Agriculture and Markets.)

serve large areas, which has obvious disadvantages. In the U.S.S.R., where this type of agriculture is practiced on state-operated farms, settlement is more compact, for the workers live in villages. This makes conditions quite different from those in our own country and in other parts of the Americas, entirely apart from differences which result from governmental organization and the practice of state socialism.

Dairying. Dairying is a variant of general farming or diversified agriculture in which the production of milk dominates the economic activities of the farm. It is generally the most important type of farming in well-watered areas with cool summers, on the poleward margin of those regions where "corn is king," and elsewhere in good "hay and oats country," particularly near urban markets for milk and other dairy products. Thus its development has accompanied city growth. In New England and parts of New York, where extensive farm abandonment occurred with opening of the West with its productive and "free land" to settlement, dairying has, as an accompaniment of industrialization and urban development, given a new lease on life to agriculture in many localities. There, fine herds are common, and purchase of supplementary feed and heavy feeding are the rule, to ensure maximum returns.

Dairying is likewise important in Minnesota, Wisconsin, Michigan, and across the International Boundary in Canada. In this region, most of which is glaciated, dairying generally dominates the farm economy, in Wisconsin to an extent that the state is sometimes known as "America's Dairyland." The physical basis for

the dairy industry in this part of the United States and Canada is topographic, drainage, and climatic conditions which ensure good pasture, but limit crop production.

The major crops grown include corn, oats, and hay. There is also some production of barley, occasionally grown as a mixture with oats; grain sorghum or "cane," either alone or with corn for silage; and soy beans for beans, or fodder and silage. Other crops include wheat, rye, root crops, and potatoes, on variable though generally small acreages.

The relative importance of these crops changes from area to area and, on the individual farm, from year to year. Occasionally, what is normally a minor crop may assume so much local importance, as do potatoes in the Aroostook area in Maine, that milk is displaced as the major farm product, though this is not common. In general, wherever it is possible to grow corn with a fair degree of success it is the most important cereal, especially of late years with development of hybrid varieties which will mature in the available frost-free season of most years, for, even if it does not mature fully, it can be fed or used for silage. On a well-managed farm in the central dairy belt of the United States, the attempt is made to keep a balance in acreage between corn, oats, and hay on the cropped land to secure a satisfactory rotation; even the permanent pasture is often handled to ensure maximum carrying power.

The cattle are dominantly dairy types such as Holsteins, Guernseys, Brown Swiss, and Jerseys. Though milk is the most important output of dairy farms, there is some production of pork veal, beef, and poultry. The relationship between the values of these is variable with area, year, and the individual farm. Veal production, for example, is affected by whether the farmer elects

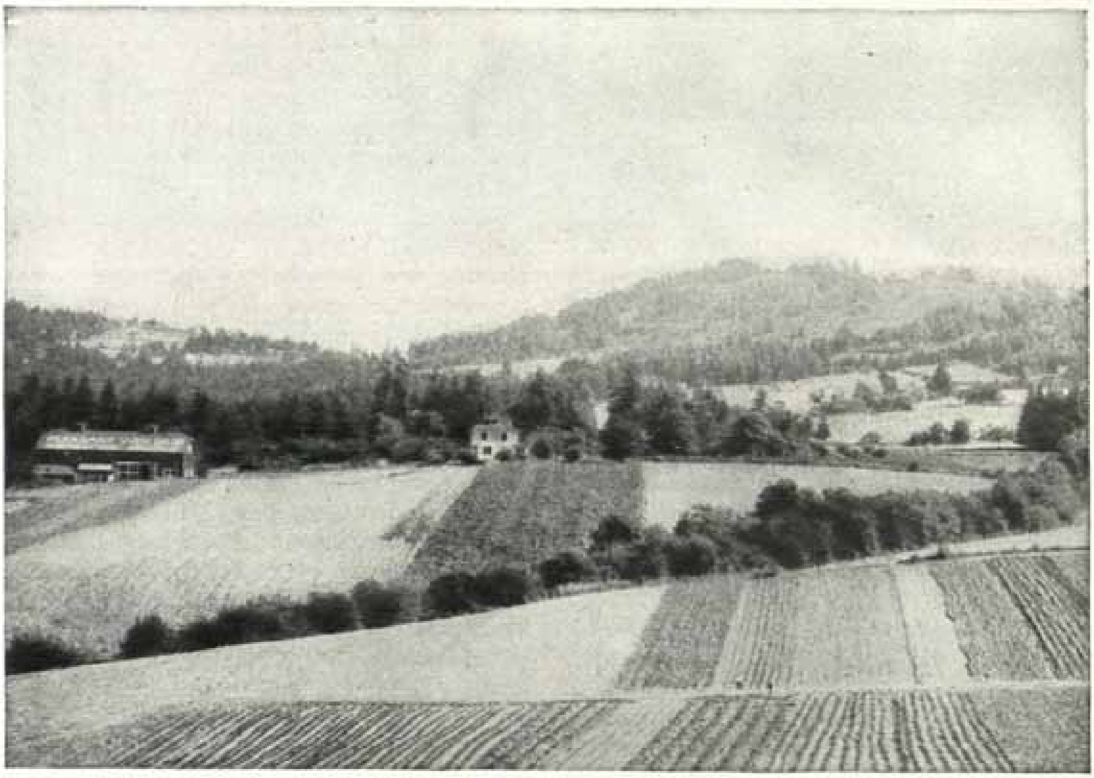

FIG. 310. A prosperous dairy farm in the Willamette Valley, Oregon. Though corn is here of less relative importance than in the corn belt, the agriculture is equally diversified, major crops including wheat, oats, corn, and hay in addition to barley, rye, potatoes, and several others of less consequence. This crop system favors development of an animal industry, particularly dairying. (Courtesy of the Portland Chamber of Commerce.)

FIG. 311. Irrigating a field of lettuce on a truck farm in New Jersey. The irrigation system consists of overhead pipes from holes in which water issues as an artificial rain, when turned on as shown in the view. Such irrigation to supplement natural rainfall is profitable, for it enables application of water during critical periods of growth, thus preventing either a partial or total failure of the crop, which yields high returns per acre under cultivation. (See also Fig. 150.) (Courtesy of the Keystone View Company.)

to raise his heifer calves or "veal" them and sell more milk; the number of hogs, by the success of the corn crop; and the importance of the poultry industry, by the price of feed and market conditions. The production of all is affected greatly by governmental policies, especially of late years.

Whether the dairy product will be milk, butter, or cheese is dependent primarily on proximity to markets. Near cities, it tends to be fluid milk; with increase of distance from urban centers, butter and cheese. This is true in Europe as well as in the United States. Recent production in the United States, however, has been so greatly disrupted by governmental action that this relationship has been considerably altered.

Dairying represents very effective land use, in New England, of much land which would otherwise remain idle or revert to forest. It is, however an economic activity of the Western world only, for markets are lacking in the Orient. Under its practices, the soils are put to effective use and their productivity is conserved or even increased, since commercial dairying involves feeding of the crops grown and, often as well, purchase of grain and fodder from other areas. Further, the farmer is able to use his time effectively, for his cultivated crops require attention part of the time; the animals, at all seasons. Therefore, even more than other types of agriculture, dairy farming affords practically continuous employment.

Intensive and Specialized Farming. Wherever production is limited to one or more vegetable or fruit crops, generally grown on relatively small units of land worked by individual producers, a garden type of agriculture develops. Where specialization is in vegetable crops, the farms are known as "market" or "truck" gardens, the distinction between the two, not always sharp, being based largely on whether production is principally of fresh vegetables for city markets or for canneries. Market gardens are generally of small size and near the cities which serve as outlets for their production. Wherever possible, they are located on lighter soils, preferably the better sandy loams, which dry out and allow early planting and marketing of the crops grown. Sometimes the organic soils, peat and muck, find similar use. In either case, heavy fertilization is the common practice, for returns per acre from these garden crops are sufficiently high to warrant the expenditure necessary to supply the essential mineral plant nutrients lacking in the soils. Truck-gardening operations, by contrast, may be carried on far from the urban centers which absorb the production. As with market gardening, the areas devoted to such use are generally those of lighter soils and, sometimes, peat and muck land. Heavy fertilization of crops is a usual practice, to ensure profitable yields of good quality. The products of the truck gardens find their way to consumers in both canned form and out-of-season crops. Thus the "truck" farms of the Gulf Coast, Florida, California, and other southern areas supply vegetables in both winter and spring to the city populations of the North, before the local garden farms have crops ready to market.

FIG. 312. Threshing peanuts at Holland, in the truck gardening area near Norfolk, Virginia. This particular part of the sandy coastal plain specializes in growing peanuts rather than other vegetable crops, being the most important peanut producing area in the United States. (Courtesy of the Norfolk Advertising Board.)

The major market- and truck-garden area of the United States borders the Atlantic seaboard and the Gulf Coast from New England to Texas, for there soils are sandy and access to markets is good. A second center is in southern California, which enjoys a climatic advantage. Scattered throughout the country are others of less extent and importance. Production of vegetable crops cannot absorb more than a small fraction of the land suitable for such utilization because of lack of market. Thus islands of market and truck gardens are often surrounded by extensive tracts of land, either not in use and growing up in scrub timber or, if in use, devoted to relatively unprofitable general farming; or, in Florida, even to the extensive grazing of cattle. The limited areas which are in use for the production of garden crops, however, represent examples of very effective use of low-grade soils. It will be noted that, in part, particularly for market gardening, location rather than soils is the principal advantage which makes such use possible. Even with truck gardening, the same is true to only a slightly lesser extent.

The farmers of certain areas of highly specialized agriculture concentrate on the growing of fruit rather than vegetable crops, the fruits ranging from berries, such as strawberries and raspberries, to tree fruits like apples, pears, peaches, cherries, and others; and from those of the cooler regions, such as those mentioned, to others of the subtropics: oranges, lemons, and the pomelo or grapefruit. The producing regions are therefore widely scattered, but tend to be localized in hilly

areas, where slopes and effective air drainage afford a considerable degree of protection from frost damage, and near lakes, which decrease the probability of loss from frost. Thus there is an important grape-growing district extending westward from the lake region of southern New York, through the islands of Lake Erie, into the hilly moraine country of southwestern Michigan. Similarly, there is an important commercial apple-orchard industry in New York and on the east shore of Lake Michigan, as well as in southern Ontario across the International Boundary, where comparable favorable conditions occur. Farther to the east, in Canada, the sheltered slopes of the Annapolis Cornwallis Valley of Nova Scotia supply a suitable location for orchards and afford the environmental basis for the most important commercial apple-growing industry of our neighbor to the north. Again, there are several areas farther south where tree fruits are grown commercially. Such are the citrus fruit-producing districts of Florida and the Gulf Coast and, farther north, the fruit-growing regions of the Ozarks, where slopes afford frost protection. Scattered throughout the same area are many small farms which specialize in berry production, for example, of strawberries, the crop maturing at various times in different areas, so that the supply is continuous for a period of several months.

The crops grown in irrigated areas tend to be those which yield relatively large returns per acre of land under cultivation because costs of production are high, since water must be purchased and markets are generally far away. Only where demand for such crops fails to keep pace with production possibilities is the growing of bulky, low-value crops desirable, except to supplement other farm activities. Much of the land under irrigation in dry areas is therefore devoted to the growing of vegetable and fruit crops for city markets.

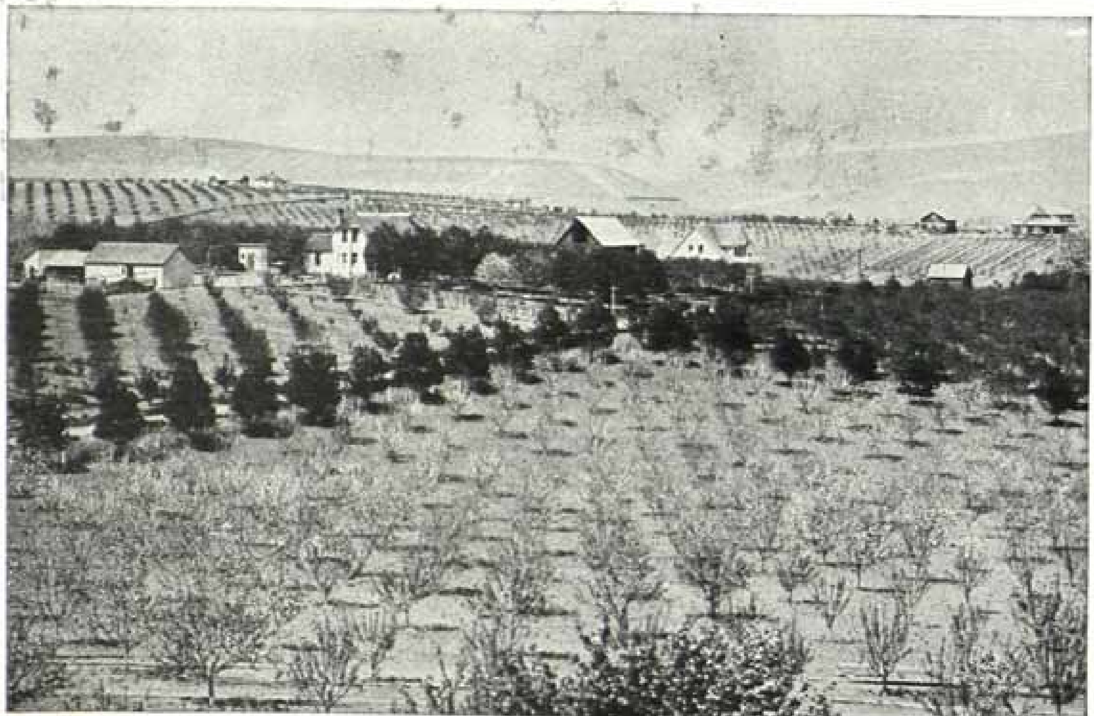

FIG. 313. An irrigated apple orchard in eastern Washington. Here, individual landholdings are small and in a high state of cultivation; houses are relatively close together; and maintenance of community services is simplified by the concentration of population in a limited area. Markets in the eastern United States have been obtained and held by advertising and supervision of grades and packing, so that uniformity of the product is assured. Only by such a procedure is success of such irrigated commercial apple orchards possible. (Courtesy of the Washington State Progress Commission.)

This is true throughout the western United States and particularly so in California, where specialization of agriculture has been carried far and facilities for publicizing and marketing the products have been developed to a high degree of efficiency. There, one locality may produce rhubarb, another melons, a third, lettuce or some other crop. Where this concentration on production of a single crop for widely scattered, faraway consuming areas occurs, it is possible for combinations of producers to market the crop effectively. This would be impossible if each farmer grew such a variety of crops that a sufficient volume of no single one was available to make establishment of the necessary marketing connections practicable.

Truck and market gardening and commercial fruit growing require much hand labor. This produces a condition unusual in American agriculture, where the tendency is to use machinery, even in milking, to lighten farm work. Since the local labor supply is often inadequate in the areas of garden agriculture and commercial fruit production, it is generally necessary to depend largely on transient labor, frequently recent arrivals in this country. This often creates a social problem, the solution of which is not yet in sight.

As a result of the generally small landholdings and the considerable labor requirement in the garden types of Occidental agriculture, farm populations are much above the average for those of other agricultural areas in the United States. Therefore social contacts are assured and, in some instances at least, an almost garden-city type of community results. In many respects, this has manifest advantages, offset to some extent, however, by the large numbers of transients without permanent interest in the community welfare.

QUESTIONS AND EXERCISES

1. In what essential particulars does Occidental agriculture differ from that of the Orient?
2. Trace briefly the evolution of Occidental agriculture. From where were the crops and domestic animals derived?
3. What was the pattern of early agricultural occupation in western Europe? Describe the land use and villages of that period.
4. What are the major types of Occidental agriculture?
5. From what type of agriculture did general farming and the associated animal industries evolve? What practices are involved in this type of agriculture? What shift in emphasis has occurred with the passage of time? What has caused this shift? What are the objectives of this type of agriculture?
6. What are the objectives in subsistence agriculture? Where is this type of agriculture practiced in the United States? Why? Where is it practiced in other parts of the world? What is the importance of the animal industries in subsistence agriculture?
7. Describe the practices of diversified agriculture. State the crops grown and their relation to the animal industries. What introduces variation in the exact pattern of agricultural practice in specific areas?
8. To what types of areas is commercial grain farming normally restricted? How is the land used in such areas? What are the crops grown in such areas? Why does such farming often involve great financial risk?
9. State the agricultural objectives in areas of commercial grain farming. Why did agricultural invasion of the steppe grasslands work a revolution in agriculture? Why was such invasion so long deferred?
10. Discuss the differences between commercial grain farming in the United States and that of the "collectives" of the U.S.S.R.
11. Why is commercial grain farming restricted to Occidental areas, except in the U.S.S.R.? Why do the boundaries of the areas of commercial grain farming fluctuate? May this type of agriculture be expected to expand materially in the near future? Why?
12. Of what type of agriculture is dairying a variant? Where is dairying the common practice? How is the land used in such areas? What relation does meat production bear to dairying?
13. Explain how dairy farming represents effective use of the land.
14. Why has dairy farming increased in relative importance in the United States of late years? Where and why has it given a "new lease on life" to agriculture in some instances?
15. What determines whether dairy production will be of milk, butter, or cheese? Why is there practically no development of the dairy industry in the Orient?
16. Describe the general characteristics of the garden type of agriculture. Why is irrigation a relatively common practice in areas with this type of production?

17. Describe the characteristics of market and truck gardening. Why are the lighter soils better for such use? Why is it possible to use organic soils for this type of production? Where are the principal areas of this type of production in the United States? Why?
18. Where are commercial fruit-growing areas commonly located? Why? How do all garden types of agriculture which are successful represent effective use of the land?
19. What is meant by irrigation? Where is it a common practice? What are the types of crops grown with irrigation? Why? What handicaps are always associated with irrigation agriculture?
20. Contrast the settlement patterns associated with the different types of Occidental agriculture.

SELECTED REFERENCES

Agricultural Yearbook, U. S. Department of Agriculture, Washington, 1921, 1922, and 1923.

Many Yearbooks of the U. S. Department of Agriculture are of great value to geographers. This is particularly true for those of 1921, 1922, and 1923, which contain descriptions of the development and production of our major crops and similar treatments of the principal animal industries.

Chapter Thirty-Three

PLANTATION AGRICULTURE

The Initiation of Plantation Agriculture. During the centuries when attainment of self-sufficiency was the common objective in Occidental agricultural practices, standards of living remained low, for it is impossible to meet many and varied needs adequately from the resources of limited areas. Thus there was little in kind, and often in quantity as well, to divide in the agricultural villages of the Middle Ages described in the preceding chapter. This ensured relatively poor living conditions for the more fortunate; those who received least often lived in squalor. Today, even persons in very modest circumstances in this country fare better and have far more conveniences and comforts than those enjoyed by the feudal lords of the agricultural villages of bygone days.

These conditions persisted without material change for a large fraction of the world's white population until improvement of transportation facilities made it practicable to obtain goods by exchange, rather than to depend entirely upon locally available resources to satisfy all needs. Then, and only then, did specialization of production in the Occidental agriculture of intermediate latitudes become both a possibility and a reality.

Further, as the known area of the world increased in extent, new products became known. At first, these were high in price and little used, for producing areas were far away, transportation facilities were poor, transportation costs were high, and so the demand for them was necessarily limited. As time passed, however, and production became more specialized and restricted to areas where conditions were most favorable, so that costs of production decreased, standards of living rose with the possibility of satisfying desires at prices within the reach of many. Thereafter, demand for the products of other areas, and even for new products from the faraway regions of the lower latitudes, developed and increased.

This later led to invasion of the tropics by white populations, and the growing of crops with Occidental agricultural practices, modified to some extent to meet the new conditions. This marked the initiation of what is known as "plantation agriculture." With invasion of the lower latitudes and development of plantations, this new type of production sometimes displaced and sometimes existed side by side with migratory or other subsistence types of agriculture, though these were often affected somewhat by white influence.

The inauguration of plantation agriculture accompanied rising standards of living in the higher latitudes, where both diversification and specialization of effort had become possibilities, for reasons which have been enumerated previously. It resulted from either new or increased demand for those products of the soil which can neither be grown successfully in the higher latitudes, except occasionally when heavily subsidized by government, nor obtained to advantage from the tropics in sufficient quantity when grown by native types of cultivation, without white supervision.

Location of Tropical Plantations. Not all parts of the tropics are equally well suited to the development of plantation agriculture. Some have too heavy and too continuous rainfall; others have too little precipitation. Again, temperature conditions are not always adapted to growing the products desired, nor are they always favorable for man. Further, frequent, strong winds, topographic, drainage, soil, and vegetation conditions often handicap, or may even prevent

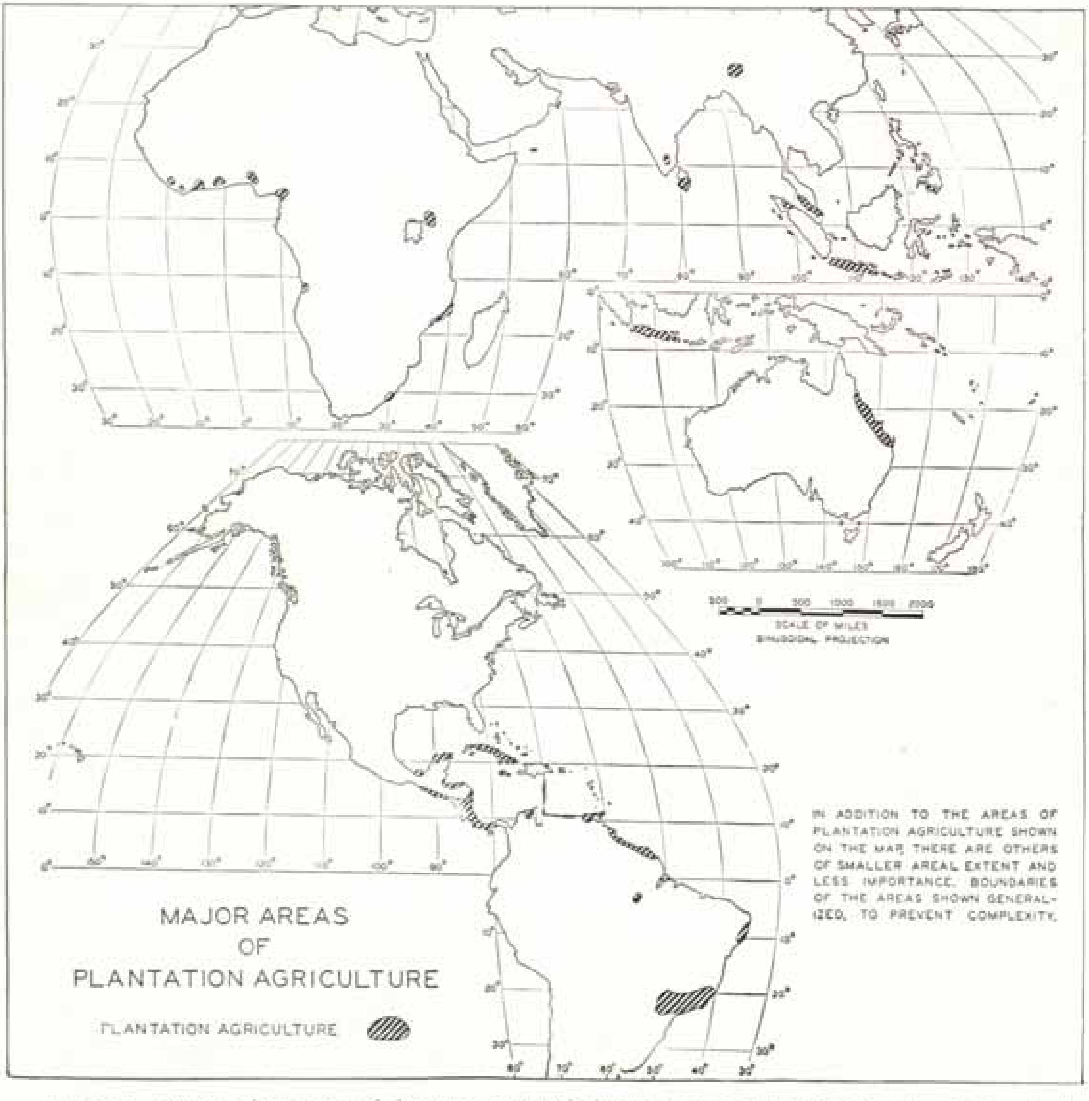

FIG. 314. Map to show some of the major areas of plantation agriculture, Occidental agriculture in the tropics.

plantation development. Even though all other factors seem favorable, an area may be so inaccessible that it is unsuitable; a satisfactory labor supply may be unavailable; or instability of government or governmental regulations may deter capital from venturing. At present, this last factor promises to become more important in the future than it has been in the past, in view of the ambitions of tropical populations to throw off the "shackles" of colonial control.

Even today, therefore, plantations are restricted to a relatively small fraction of the total area of the tropics, as may be seen by reference to Fig. 314, a highly generalized map showing the approximate location of most of the present producing regions. For the most part, these tend to be confined to seacoast areas, or those served by navigable rivers and rail lines, but not too far from seaboard. They are likewise more important where rainfall is adequate, but not excessive, with the dry or drier season of some length. Thus they are more highly developed in trade wind and monsoon areas, where the seasonal range of temperature is appreciable and sensible

temperatures are tolerable, than in the heart of the heavily forested regions of the doldrum belt. There, temperatures, both actual and sensible, are continuously high, and heavy rainfall throughout the year, a dense forest cover, and poor health conditions all conspire to handicap plantation development.

Crops of Tropical Plantations. Inasmuch as the major objective of plantation agriculture is surplus production of some crop, grown principally to meet the needs and demands of intermediate latitudes, there is great specialization of effort in this type of agriculture, in addition to variation in the major product from area to area. Thus one region concentrates on growing sugar cane; another on producing rubber; a third specializes in bananas. Again, it may be a beverage crop such as coffee or tea; cacao, used both as food and for a beverage; copra, valuable for its oil; pineapples for canning; or some other crop. It will be noted that some of these products are raw materials used by industry, for example, rubber, copra, sisal, and sugar; some, such as coffee and tea, are beverages; still others, bananas and pineapples, are "fruits," used as food. Again, some are used both by industry and for human consumption. In the aggregate, however, industrial raw materials secured from tropical plantations are more important than the foodstuffs this type of agriculture supplies to intermediate latitudes.

In addition to the crops grown in surplus and for sale on such plantations, there is often some production of others to afford a local food supply for the plantation laborers, though this is of secondary and, often as well, of rather minor importance. In general, it is true that development of tropical plantations has reduced production of food for local use in the areas where they have been established, so that import of food into formerly self-sufficient areas has become necessary to meet the needs of the plantation laborers. It is likewise true that plantation agriculture has probably subtracted from, rather than added to, the total food supply of the world.

Ownership and Operation of Tropical Plantations. Most tropical plantations are owned by whites: some by corporations, others by families or individuals. In either case, it is normally absentee ownership, actual operations being directed by white managers who oversee the work done by colored laborers. In the early days of plantation development in the Americas, workers were secured by impressing local Indian populations. Later, these were replaced by slaves imported from Africa, which accounts for the present large Negro population of many Caribbean areas. In southeastern Asia and adjacent islands, where there is much local overpopulation, most of the necessary plantation labor has come from India, South China, the Philippines, and other near-by regions, imported under contract to work for a specified number of years. Later, some of these workers return to the home region; others remain as permanent residents. Some of these, notably the Chinese, tend to gravitate to the cities, where they enter business so successfully that they may dominate the economic life of the local community.

Effects of Tropical Plantations on Native Production. Wherever the plantation type of agriculture has become established in the tropics, it has affected the native economy and standards of living, as well as population density and distribution. This is true even where it exists side by side with migratory or sedentary types of primitive cultivation; where these have been displaced, the change is even more pronounced. In Liberia, for example, though occupants of the leased land were dispossessed, employment as free laborers is now available on the holdings of the Firestone Company, where no such opportunity for gainful employment existed previously. This enables support of additional numbers and permits satisfaction of many wants created by white intrusion, thus affecting standards of living. Similarly, the Dutch have been successful in increasing the ability of their colonial holdings in the East Indies, notably Java, to support additional numbers, as well as in improving living conditions. In part, this has been accomplished by affording employment for the increased numbers, in part by development of a market for native production with the establishment of plantations.

The Economic and Social Structure in Areas of Plantation Agriculture. The labor employed on most tropical plantations is imported, largely transitory, and the manual laborers are drawn from several colored populations of the lower latitudes. This importation of diverse colored populations to work on the plantations leads to miscegenation, or racial admixtures of many types, which creates a "melting pot" problem in

FIG. 315. Bananas ready for harvest, in Cuba. Note the position of the bananas on the "stalk." After the crop has been harvested, the plants are cut and allowed to rot between the rows. Reproduction for the next crop, which will ripen one year later, is from suckers which develop at the base of the plant stalk. (Courtesy of the U. S. Department of Agriculture.)

many areas where the plantation type of agriculture is important, for example, in Hawaii.

Even though whites are relatively few in number, however, they normally dominate the economic activities and exercise political power far greater than that which would be indicated by their numbers. Further, the color line is generally, though not always, sharply drawn in areas of plantation agriculture. This becomes of especially great importance in the Orient, where "face" plays such an important part in the standing and affairs of the individual. This is an organization of society very different from the one to which we are accustomed, as well as one resented by the colored populations. Therefore it is one which is causing considerable concern at the present time.

Types of Plantation Agriculture. There is sufficient diversity of production and production methods in plantation agriculture to make a detailed description of all kinds of tropical plantations impracticable in our survey of this type of agriculture. Therefore consideration will be limited to a brief discussion of those where bananas, a fruit crop used as food, are grown; of those where sugar cane, raised for sugar to be used both as a food and industrial raw material, is the principal crop; and of those where rubber is produced for industrial use.

Banana Plantations. Though the banana is native to southern Asia, spreading from there to Africa and, eventually, to the Americas, most of the present commercial production of the fruit is in Caribbean areas, with some additional surplus output from both the east and west coasts of Africa and a few other less important areas.

The producing areas are all tropical lowlands, not subject to violent winds, with well-drained, high-lime soils, where both heavy and well-distributed rainfall supplies the necessary water, except as supplementary irrigation may be practiced during the drier season in order to secure continuous yields. The production from the Caribbean area is marketed in both North Amer-

ica and western Europe, but principally in the United States and Canada, which absorb about 60 per cent of the crop; the African production goes to Europe, largely to Great Britain.

Because of the rather exacting requirements of the crop, great care must be exercised in selection of a location for the growth of bananas, if satisfactory yields are to be secured. After a desirable site has been selected, and has been secured by lease or purchase, the land is cleared, drained, and banana "bits" or rhizomes are planted. The crop matures in one year, each individual plant attaining a height of about 25 feet and bearing a bunch of fruit. After the crop has been harvested, the plants are cut and allowed to rot between the rows. Later, suckers which will produce a crop the following year develop from the root stalks. Each of these grows and bears a bunch of bananas in 12 months. This process is repeated year after year for perhaps 15 years. Then new land must be cleared and planted to ensure continued profitable production. By having plants of different ages and stages of development on the plantation, and by use of overhead systems of irrigation during the drier season, it is possible to harvest bananas throughout the year. This is desirable for profitable operation, in that it permits effective marketing of the crop and use of equipment and labor supply.

Each plantation has its own railroad system. This is connected to the port which serves the plantation by a company-owned rail line. Transported by these lines, the bananas, which are cut green and allowed to ripen in the bunch, are loaded by machinery into the ventilated, refrigerated holds of ships which can be heated during the winter months, if necessary, to keep the bananas from freezing in transit to northern destinations. These ships are likewise company-owned and operated. It will be noted that banana production and marketing is a large-scale business enterprise, involving investment of much capital, a common characteristic of all plantation agriculture. Sometimes this investment is in countries with none too stable governments, which may explain in part some of the activities of the banana producers in the so-called "banana republics."

Bananas were first brought into the United States from Cuba in 1804. Even as late as 1876 they were so little known and used in this country that red bananas, wrapped in tinfoil, were sold at the Philadelphia Centennial as an exotic curiosity. Today, less than 75 years later, consumption in the United States repeatedly exceeds 60,000,000 stems annually, or approximately half a stem per capita. This change is only one of many which have resulted from the fact that the older isolation which fastened essential self-sufficiency on the world's agriculture for so long has disappeared among more advanced populations.

Sugar Cane and Sugar Production. The production of sugar cane is important in many tropical regions where elevations are not too great. In Africa, it is grown both in Egypt and on the east coast of the continent; in Asia, it is an important crop in India, Burma, and in several other parts of the southeast; in the East Indies, it occupies considerable acreages in Java and elsewhere; in the mid-Pacific, the same is true in Hawaii. Farther to the north, the Philippines are also important producers of sugar. In the Western Hemisphere, it is a crop of considerable importance on the low, rolling plateau of eastern Brazil, in several small coastal valleys of Peru, and in parts of northern South America and other Caribbean areas. In Cuba, it is the most important crop grown on the island.

Everywhere, sugar cane is a crop of warm climates, good soils, and areas of considerable precipitation, except where grown under irrigation. For optimum conditions, most of the rain should fall during the growing season; during the period of maturing and harvest, and especially during the latter, it should be cooler and drier. These conditions are satisfied in trade wind and monsoon areas, where most of the world's commercial crop is produced.

Sugar cane is grown with a considerable variety of practices, and with great variation in the organization of the industry. In India, where "gur," an unrefined brown sugar, is produced for local consumption only, the crop is commonly grown on small landholdings, and the same is true in many other Oriental areas. By contrast, sugar cane is generally grown in Hawaii and Cuba, both large producers, with a plantation system of agriculture. Cuban practices will, therefore, serve and be used to illustrate this type of production of sugar cane and sugar.

Sugar Production in Cuba. Sugar cane was introduced into Cuba as a crop early in the sixteenth century, as an accompaniment of Span-

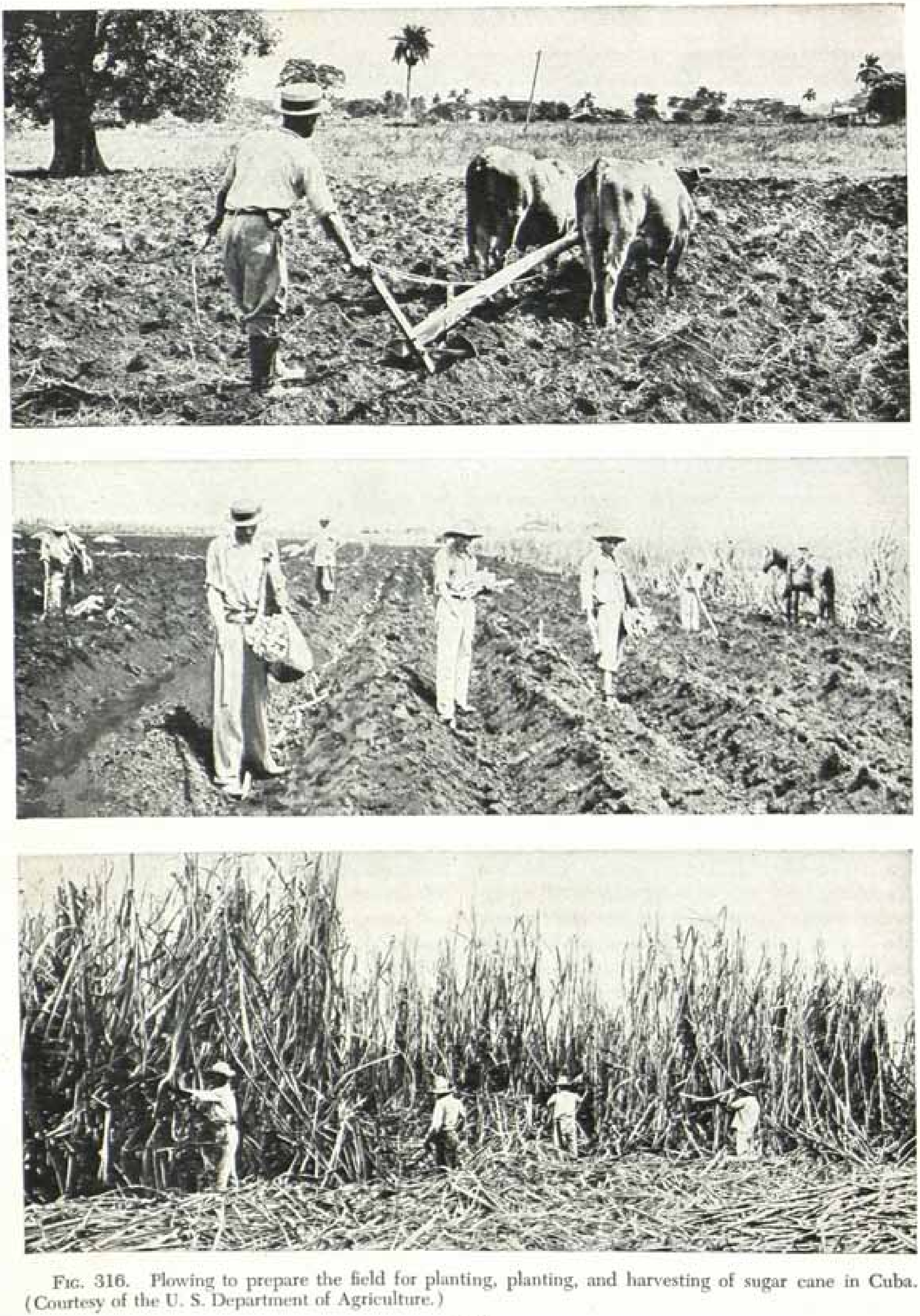

FIG. 316. Plowing to prepare the field for planting, planting, and harvesting of sugar cane in Cuba. (Courtesy of the U. S. Department of Agriculture.)

ish occupation and agricultural development of the island, though early production was small, for demand was limited in those days when essential self-sufficiency was still the rule in most parts of the Western world. For the past half century or more, however, its production has been important. Today, half of the cultivated land of the island is given over to the crop; the production of sugar and its by-products employs one-third of all Cuban labor; these same products normally make up approximately 80 per cent of the value of all Cuban exports; and Cuba supplies about 20 per cent of all the sugar entering international trade.

Most of the commercial production of sugar in Cuba is organized in large units, around "centrals" or mills, the largest of which has an annual capacity of 340,000,000 pounds of sugar. These are surrounded by extensive acreages of cane which supply the mills. The farmers or "planters" of these areas are organized in "colonos" and grow cane under contract, such groups accounting for from 80 to 90 per cent of the total Cuban sugar-cane production.

There is considerable more or less primitive practice, and much manual labor employed in plowing the land, in planting the crop, and in cultivating and harvesting the cane, as in other types of plantation agriculture. Plowing is commonly done with oxen and rather crude plows, as shown in Fig. 316. Planting is by hand, pieces of cane, from which sprouts develop at the joints, being dropped in the furrows as shown in Fig. 316. One such planting will last for several years, for the cane ratoons or sprouts from the old root system, but with decreased yields as the years go by. Therefore part of the acreage is replanted each year to ensure profitable yields. In Hawaii, two ratoon crops are normally harvested between replantings; in Peru, five; in Cuba, from four to eight. Since replanting is expensive, the number of ratoon crops which can be cut to advantage affects the desirability of an area for growing sugar cane. After planting, cultivation is neces-

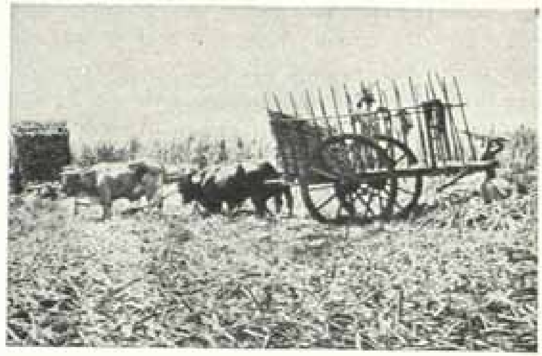

Fig. 317. Hauling sugar cane from the field to the loading platform of the "central" rail line with ox carts, two of which are shown. The one at the left is loaded with cane, that at the right is empty. Note the substantial construction and the large wheels of the carts, necessary on the rough ground. (Courtesy of the U. S. Department of Agriculture.)

Fig. 318. A trainload of sugar cane on its way to the "central," with the right of way flanked by fields of cane which has not been cut. (Courtesy of the U. S. Department of Agriculture.)

sary until the cane shades the ground and keeps other growths down. When the crop is mature and ready for harvest, 12 to 15 months after planting, it is cut with a machete or heavy knife as shown in Fig. 316. Then the top is removed, the leaves stripped off, and the cane is cut into 4-foot lengths. After this, it is loaded on substantial two-wheeled carts, such as those shown in Fig. 317, for hauling to the loading platform of the rail line which serves the central. On the average, each mill is served by 380 miles of such lines. It will be noted that, as with other types of plantation agriculture, many of the operations are highly mechanized, and that a large investment of capital is necessary.

Though sugar cane has been a commercial crop of importance for a relatively short period of time, its products are today in great demand for both peace and wartime uses, a fact probably still fresh in the mind of the reader. Today, sugar is not only a food, but a raw material used in making alcohol, chemical preparations in great variety, and a long list of other products. In all, the Sugar Research Foundation lists a total of nearly 150, ranging in alphabetical order from adhesives and food preparations to varnish and welding rods. This again illustrates how important the products of other areas are to continuance of present-day standards of living in industrialized societies, and that any attempts to return to the self-sufficiency of the past would be unwise, for it would result in undesirable change.

Rubber Plantations. Practically all of the world's present-day rubber plantations are located in tropical lowlands, between the parallels of 10° North and 10° South latitude, where temperatures are uniformly high, rainfall is heavy, and destructive winds are practically unknown: all conditions which are necessary for the successful commercial production of rubber. Approximately 9,000,000 acres of land of this part of the earth's surface, located in British Malaya, the Netherlands East Indies, French Indo-China, British India and Burma, Sarawak, British North Borneo, Liberia, Brazil, and limited areas elsewhere, are used for rubber production. The first two regions of the preceding list, which dominate in the world's production of natural rubber, account for more than 75 per cent of the total acreage included in rubber plantations, an area approximately three times the size of the state of Connecticut.

Though unknown to Europeans until after discovery of the Americas by Columbus, it was soon learned that rubber could be used to erase pencil marks. Therefore it was given the name "rubber" by the English; the French called it "caoutchouc," from the Indian name meaning "weeping tree." By 1791, rubber was used to waterproof cloth and, by 1800, to make elastic for garters and suspenders, as well as for surgical tubes. In those early days, however, it was high in price, $175 per pound in 1770, and used in only small amounts and for few purposes. It was not until the process of vulcanization was discovered by Charles Goodyear in 1839 that rubber became an extensively used and valuable industrial raw material. Since the beginning of the present century, accompanying widespread ownership of automobiles, its use in the United States has increased so greatly that it is in normal times our leading import in value.

At first, rubber, obtained from a milky fluid known as "latex" which occurs in the tissues of several plants, growing for the most part in the tropics, was gathered as a wild forest product by native laborers who worked for contractors, most of the supply coming from the Amazon basin, with smaller amounts from other tropical rain forest areas. During this period, two Brazilian cities, Pará and Manáos, the commercial centers of the rubber empire, enjoyed great prosperity. But not to last, for, by early in the present century, the center of the industry had shifted to southeastern Asia and the adjacent islands, where plantations of *Hevea brasiliensis,* the rubber tree native to the Amazon basin, had come into bearing to an extent that they furnished the bulk of the supply necessary to meet the steadily increasing world demand. This shift occurred because climatic conditions were equally favorable in southeastern Asia; labor supply was more abundant and the labor was more efficient; and stable government and European control of the area suitable for production tempted investment of capital. In addition, commercial and transportation facilities were available, and other types of plantations were already in operation.

Oriental Rubber Plantations. An Oriental rubber plantation affords an excellent illustration of agricultural production carried on as a business enterprise in which much money is invested. It normally consists of several thousand acres of land, of which part is devoted to growing rubber,

FIG. 319. *Top:* New planting of rubber trees on a recent clearing in northern Sumatra. Growing between the trees is a cover crop, to retard runoff and conserve the soil.

Bottom: An eight-year-old planting of rubber trees in northern Sumatra, with a cover crop between the rows. These trees are in bearing, as indicated by the marks of the "tap sheets." (Courtesy of the Netherlands Information Bureau.)

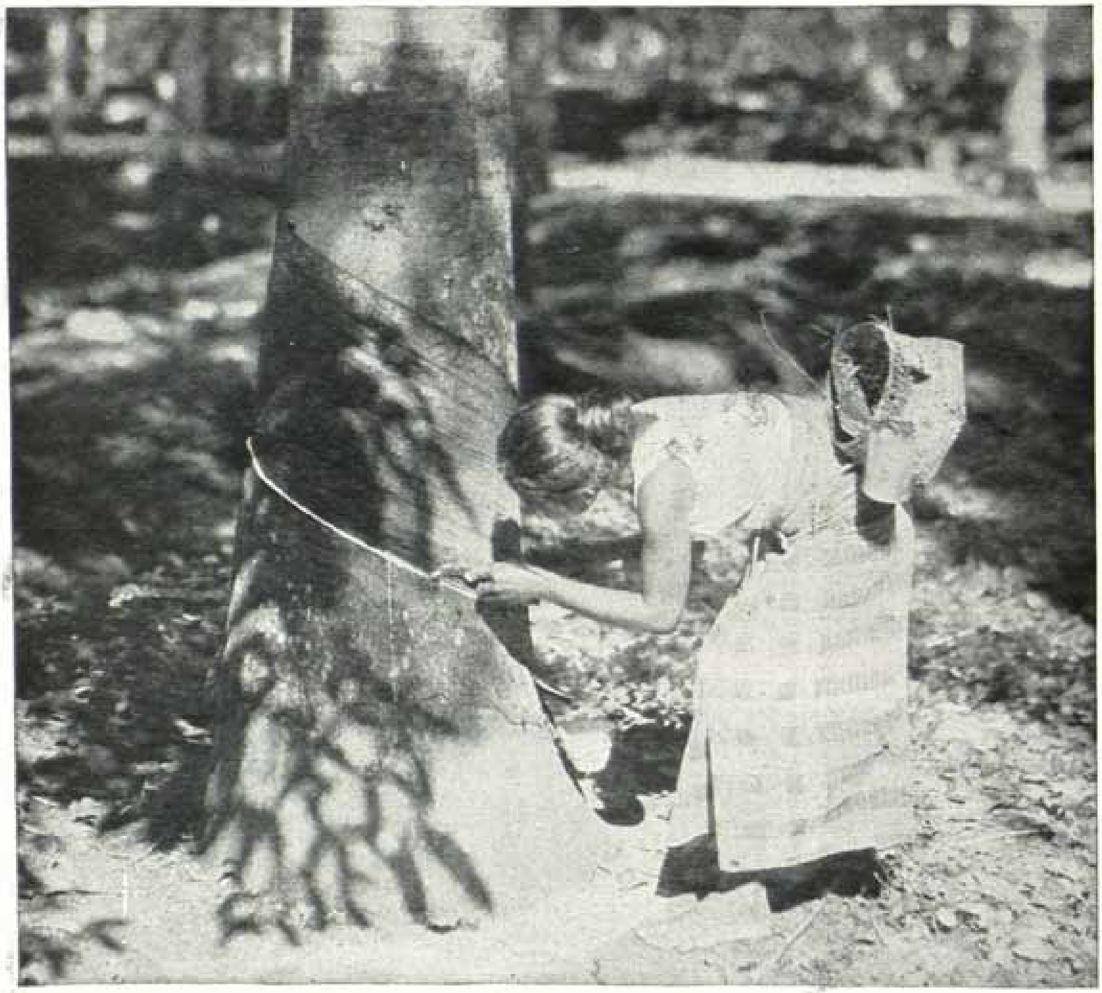

FIG. 320. Tapping a rubber tree on an East Indian plantation. This is done by removing a thin layer of bark from one side of the tree with a sharp knife or a special tapping tool, great care being exercised not to cut too deeply into the bark. Trees are usually tapped every other day between five and nine o'clock in the morning, when the flow of latex is greatest. In tapping, the bark is removed in narrow spiral strips from not more than four feet above the ground almost to ground level, the total width of the strip removed in one month being one inch or less. The latex collects where the latex tubes have been cut by removal of the bark. An experienced tapper can tap from 200 to 500 trees a day, varying with the size of the trees and his skill. Since the bark renews itself in about six years on healthy trees, the scarred portion of the trunk can be retapped so that, with proper management, a planting lasts for many years. (Courtesy of the United States Rubber Company.)

with the balance in some other commercial and a few food crops, forest, and miscellaneous uses. It is usually operated by a white manager and his staff, an office force of Eurasians, and a large number of native laborers. Such plantations require from 5 to 6 years to come into production, for the trees are not tapped until they attain a diameter of about 6 inches. After the latex or "milk" has been obtained from the trees by native laborers, who are paid according to the amount and quality they secure, it is prepared for market by chemical treatment and smoking.

The returns to investors in the rubber plantations of southeastern Asia have varied greatly. Sometimes the price of rubber has been high and profits large; at other times, rubber has sold for

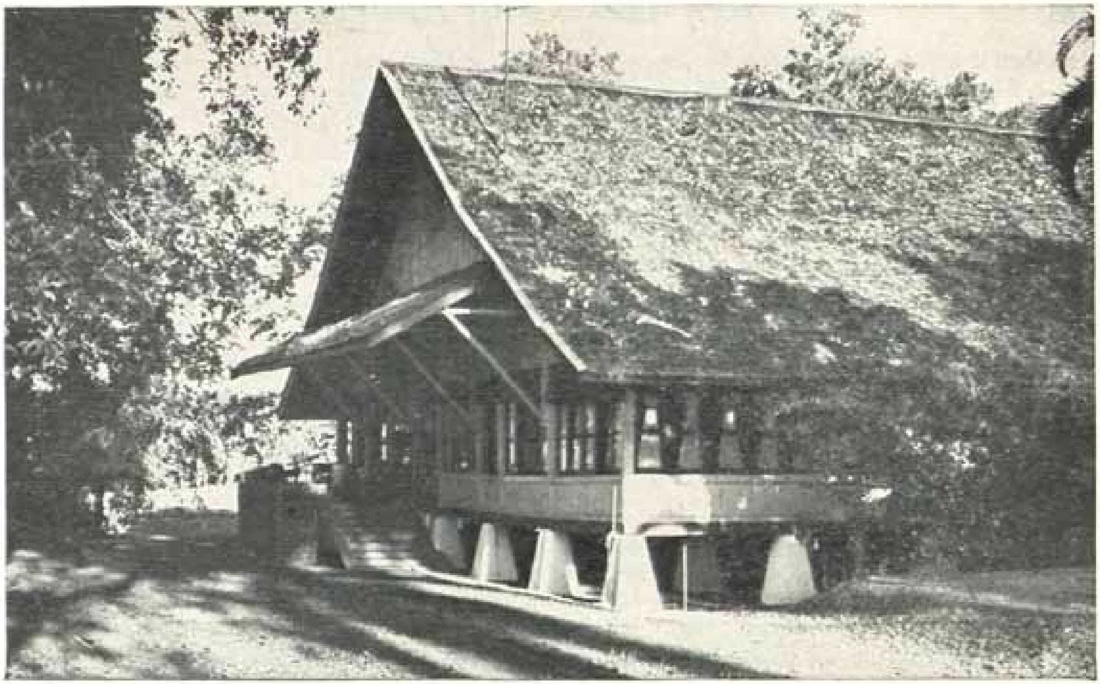

FIG. 321. *Top:* The home of the manager of a rubber plantation in northern Sumatra. Of frame construction, and with roof of palm leaf thatch, it is set on stone piers some distance above the ground as a protection against vermin.

Bottom: Houses of the Indonesian workers on a northern Sumatra rubber plantation, set in an orderly row along the street. Though small and, like the house of the manager of simple construction, they afford satisfactory quarters in this warm climate, and sanitary conditions are good. This is important, for it increases the efficiency of the labor. (Courtesy of the Netherlands Information Bureau.)

less than the costs of production on most plantations, for its price has varied from a maximum of about $3.00 in 1910 ($3.06) to a low of 3 cents a pound in 1933. Probably 20 cents is a fair price. Attempts to regulate prices by restriction of production have sometimes been moderately successful; sometimes failures. In part, this has been because of difficulty in controlling all sources of supply of new rubber, and partly because both scrap and substitutes supply competition for the plantation product. Some of the substitutes are, in fact, better than natural rubber for certain uses. Further, this competition will increase, since new processes for making synthetic rubbers are announced regularly, their quality improves steadily, and much lower prices for such products are possible with improved processes of manufacture and large volume of production. This tends to depress the price of the natural product. It is even possible that synthetic rubbers may displace all plantation rubber in time, certainly for some, though probably not for all uses.

The original home of the *Hevea brasiliensis,* the "rubber tree," was the Amazon basin, where a moist climate, deep soils, and elevations of less than 500 feet favor its growth. There, individual trees have been known to attain heights of 125 feet, with trunks more than 18 feet in girth, though the average tree on a plantation is not more than 50 to 60 feet tall. In 1876, seeds brought from the Amazon basin were planted at Kew Gardens, near London, and young trees grown from them were later sent to Ceylon, where environmental conditions are similar to those of the area from which the seeds came. From this small beginning have developed the rubber plantations of southeastern Asia, which cover an area greater than that of some of the smaller states of this country. After more than half a century, however, the rubber-plantation industry has returned to the original home of the rubber tree, the Amazon basin.

Rubber Plantations in the Americas. In order to ensure control of a supply of rubber, Henry Ford acquired a concession of 3860 square miles, or 2,471,000 acres of land, in the Amazon basin, about 500 miles upstream from Belém on the east side of the Tapajóz River, one of the southern tributaries of the Amazon, in July, 1927. There, for the first time, establishment of a rubber plantation was attempted in the original home of the rubber tree. Later, in 1934, the southeast 686,000 acres af the original grant, known as "Fordlandia," were exchanged for an equal area farther downstream, a few miles above Santarem. This tract, known as "Belterra," is now the important producing area. At present, nearly 20,000 acres and 3,000,000 trees have been planted, about three-quarters in Belterra. Though the current production is small, it is expected to be 12,000,000 to 15,000,000 pounds in 1948, when the 1941 planting at Belterra will be in production.

Brazilian encouragement of this venture included an agreement to levy no imposts for a period of 50 years, in return for which the company would pay 7 per cent of its profits to the local governments during that period; 2 per cent to the municipalities, 5 per cent to the state. Several difficulties have confronted this development. One was that the first plantings did poorly because of attack by disease and an unsatisfactory choice of site. Another was the scarcity and unsatisfactory character of the labor supply. The laborers, for example, objected to paying rent for houses built by the company because, from their point of view, houses are something "Providence, the boss, or the company provides." Again, too high wages were paid at first, which not only disrupted the local labor market and earned the antagonism of other employers, but made the workers themselves believe that the millennium had arrived, for they could work but little and still satisfy all their wants. To induce them to work steadily, it was therefore necessary to reduce the pay to 60 cents a day, which is only slightly higher than the rate paid elsewhere in the area.

This development in the Amazon basin, a few miles upstream from Santarem, the port and market center at the junction of the Tapajóz and Amazon rivers, is still in the experimental stage. The location is excellent, for both the Tapajóz and the Amazon are navigable, therefore the plantation is accessible by water. Further, natural conditions favor the growth of the rubber tree and land is cheap. This is a large-scale, efficiently managed enterprise, with its own towns, which have houses for both white and native labor, waterworks, sewers, electric-light plants, and hospitals. There are also miles of roads, docks, warehouses, and other buildings, in addition to sawmills, dry kilns, and the other facilities neces-

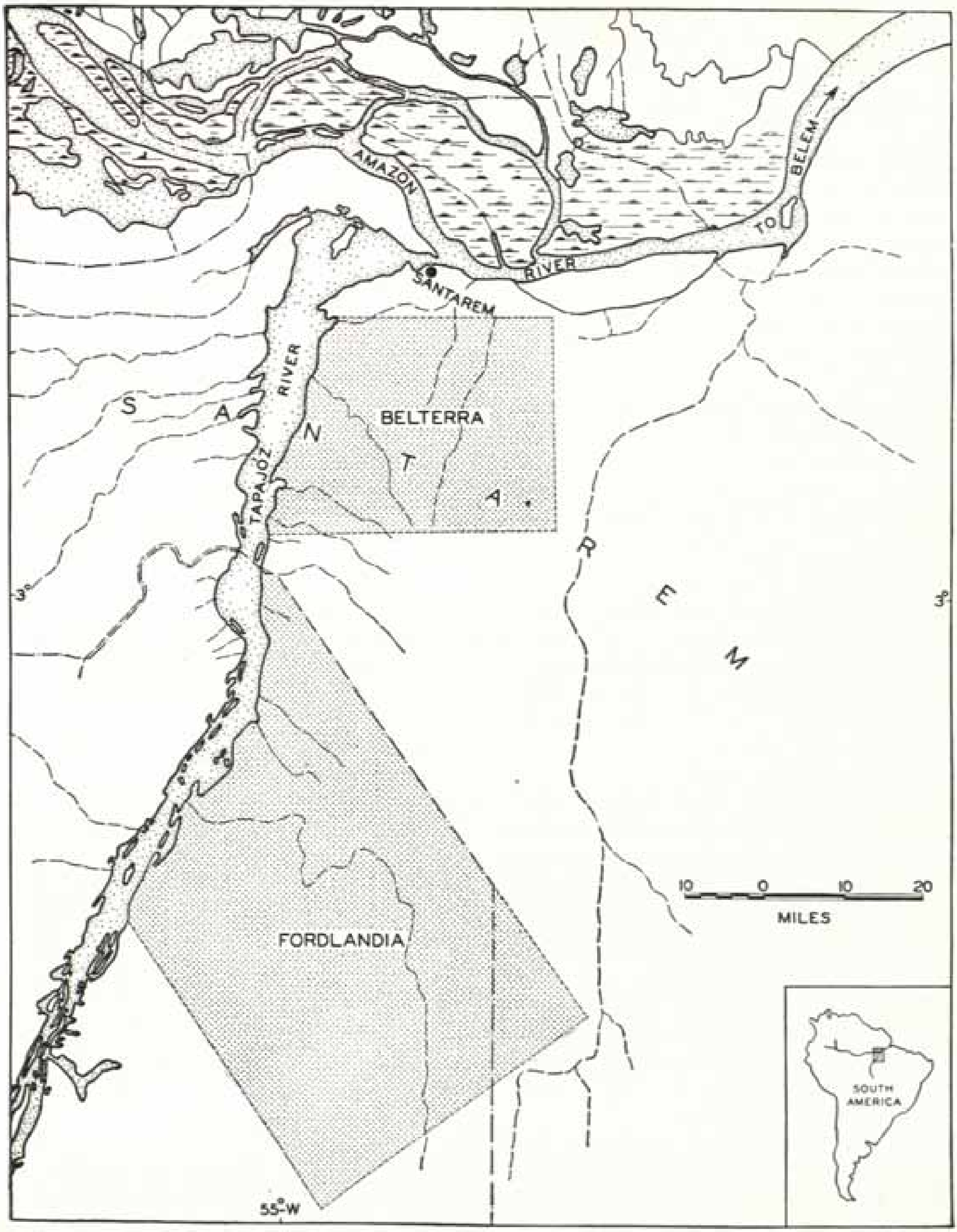

Fig. 322. Map showing the location of the rubber plantations formerly owned and operated by the "Companhia Ford Industrial do Brasil." This is the only large-scale attempt to establish a rubber plantation in the Americas, and the only one in the Amazon basin, though the attempt has been made to grow rubber elsewhere, as in Costa Rica, where, in 1945, there were about 75 small, widely scattered rubber farms.

sary to make the project essentially self-contained. This venture, involving a total investment in excess of \$15,000,000, normally employs about 2500 laborers. Today, however, it has passed out of Ford ownership; the government of Brazil accepted the Ford offer to sell for \$250,000 on December 15, 1945. Though ownership has changed, the plantations still hold forth some promise of affording a nearby source of supply of rubber in the future. This is very important for such a vital raw material, especially in times of war.

The future of rubber plantations is far from assured. Their productive capacity of 1,600,000 tons of rubber in 1941, with a record consumption of 1,100,000 tons in the same year, left a potential surplus of nearly 50 per cent. This unsatisfactory relationship between possible production and market possibilities will later be made much more pronounced by the vastly increased production of synthetic rubbers which has developed during the war, for some of these will undoubtedly retain part of the market they have captured, even when full plantation production is restored. It would appear, therefore, that some shrinkage of acreage is due, and that many marginal producers will be forced to discontinue operations.

The Population of Areas of Plantation Agriculture. Both the density and distribution of population very markedly in the regions where plantation agriculture has become established. Everywhere, it is true, the possibility for the support of additional numbers has accompanied

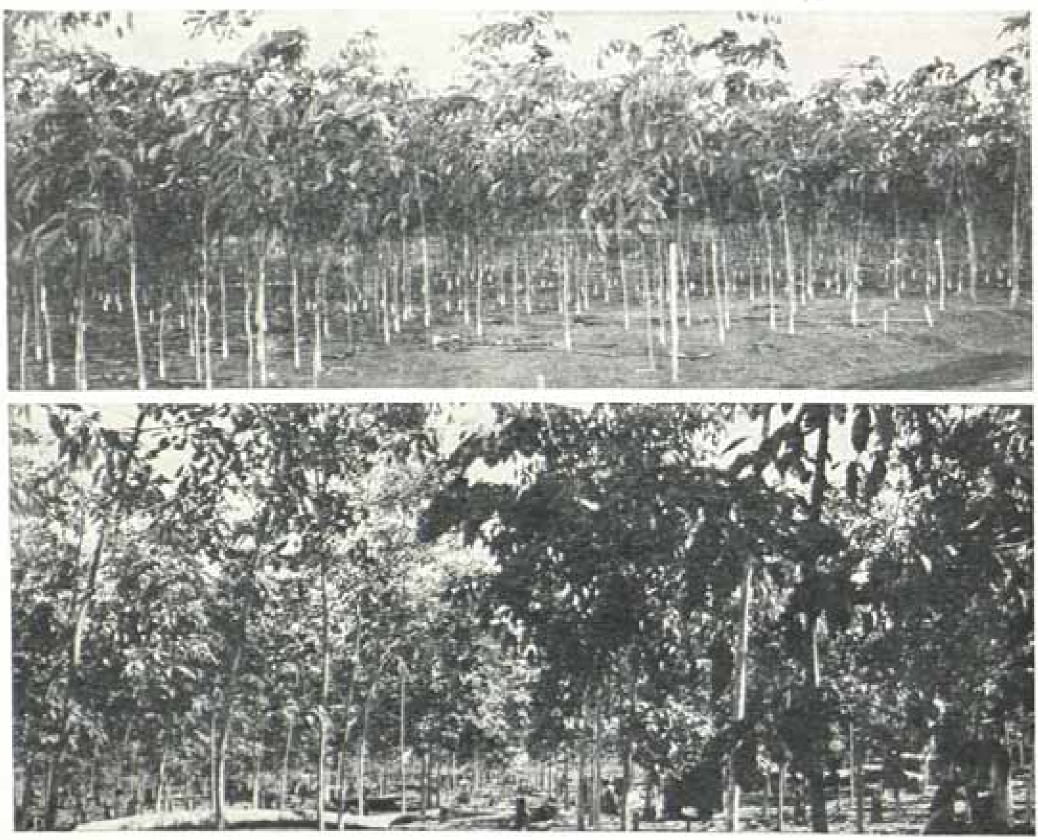

FIG. 323. *Top:* Nursery at Belterra with budded trees. Young trees are planted about 100 to the acre and thinned later, only the healthiest ones being preserved. Budding, or grafting of a dormant bud from a proved high-yielding tree, is common because it increases the yields of latex.

Bottom: Hillside planted in rubber trees at Fordlandia, with a heavy cover crop, to check runoff, loss of soil, and to simulate forest conditions. (Courtesy of the Ford Motor Company.)

development of this type of agriculture and everywhere, as well, settlement is compact on the plantations, but conditions elsewhere vary with the use of adjacent areas. In the Amazon basin, for example, the Ford plantation is bordered by undeveloped territory with few, mostly primitive, and widely scattered inhabitants, whose activities tend to be concentrated along the stream courses which serve as highways. There are few settlements of any size and, over much of the area, the population density is less than two persons to the square mile. By contrast, the plantations of the Netherlands East Indies are in many cases located in regions where population densities range from moderate to very great, and urban development is considerable. In such areas, the plantations only serve to interrupt and modify the former pattern of population distribution. Therefore there is no uniformity of population density or distribution in those parts of the tropics where the plantation type of agriculture has become established.

Semiplantation Agriculture. In addition to the plantations of the tropics, a semiplantation type of agriculture sometimes evolves in areas on the poleward margin of lower latitudes in the Western world. Thus, in our own southern states, we have what are known as "plantations," for example, the large farms on which much of the cotton is grown. Prior to the Civil War, when these holdings were worked by slave labor, this may have been their proper designation. Today, however, this may be open to serious question, for they differ materially from the rubber and other plantations of the lower latitudes, since much of the land is worked by individual tenants, often sharecroppers who receive a portion of the crop as their wage, rather than laborers working under the supervision of overseers. Further, a considerable fraction of the acreage is devoted to food and feed crops like those grown in regions of diversified agriculture in other parts of intermediate latitudes. It is probable, therefore, that it is best to consider this type of production a modification of general farming, in which emphasis is placed on a cash crop, in this case cotton.

Occidental Tropical Agriculture and Interdependence. Today, we live in an interdependent world. This has been brought home with increased force by the late war, when acute shortages developed as distant sources of supply of vital raw materials were cut off. To meet this situation, we have transferred certain crops, many grown on plantations in faraway parts of the world, particularly in southeastern Asia, the East Indies, and the Philippines, to the Americas. Thus we are now growing abaca or Manila hemp on an extensive scale in Panama; we are encouraging the production of rubber in Central and South America; we are securing teak from Panama, Costa Rica, and Honduras; and we are attempting experimental cultivation of cinchona and several other forest products in the Caribbean areas.

Though possible with the abnormal economy of wartime, it is open to question whether this production can be continued in the future at a profit, for it will be necessary to meet the competition of low Oriental wage levels. Offsetting this handicap, however, is the great advantage of controlling a source of supply in times of emergencies, and the desirability of diversification of production in Middle America. Therefore it is probable that some of the changes which have occurred during the war, for example the production of abaca, will be permanent, and it is likewise true that other modifications of Caribbean agriculture will probably develop.

QUESTIONS AND EXERCISES

1. What has caused the recent extensive development of plantation agriculture? What effect has the introduction of plantation agriculture had on other types of agricultural production in the tropics?
2. Where are tropical plantations located? Why? Why is such a small fraction of the tropics used for such plantations?
3. What crops are grown on tropical plantations? How are they produced? Do they constitute any important addition to the world's food supply? For what are most of them used? Illustrate by examples.
4. Describe the ownership and operation of tropical plantations. What is the character of the labor supply?
5. What effect has the introduction of plantation agriculture had on native populations and their economic opportunities?
6. What social and economic problems have been introduced by the practices of plantation agriculture? Why?

7. Where are the principal commercial banana-producing areas of the world located? Where are the markets for the production of these areas? What are the natural conditions necessary for the successful commercial production of bananas? Describe the methods used in growing and harvesting this crop.
8. Discuss the spread of bananas as a crop and the history of their use in the United States. Why were they unimportant for so long in this country?
9. In what areas is the commercial production of cane sugar concentrated? Why? What are the natural conditions necessary for its successful commercial production? Why is irrigation often necessary? Why is Cuban production so important?
10. Discuss the importance of cane-sugar production in the economic life of Cuba. Describe the organization of Cuban production and the agricultural practices followed in growing and harvesting the crop.
11. Where are the principal commercial rubber-producing areas of the world located? Why?
12. Discuss the history of rubber production and describe a typical Oriental rubber plantation.
13. To what extent have the returns from rubber plantations varied? Why is the future of rubber plantations far from assured?
14. Where is the "Ford" rubber plantation located? What natural advantages does this location possess? From what handicaps does this venture in plantation agriculture suffer? What is the ownership of this plantation at present?
15. What effects has the introduction of plantation agriculture into the tropics had on population density and distribution?
16. What "semiplantation" types of agricultural production occur in the United States? How do the practices in such production differ from those of the tropics?
17. What effect has the late war had on our appreciation of the fact that we live in an interdependent world? Illustrate by examples.
18. What crops have been introduced into Middle America as a result of the late war? Will it be possible to continue their production in peacetime? Why?

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Chapter Thirty-Four

FORESTS AND THE FOREST INDUSTRIES

The Variable Value of Forests. Forests have played an important role in human affairs by affecting the economic activities of man at all periods, even prior to those for which we have any written record. However, both their actual and their relative values have differed from time to time, varying both with the stage of human development and the degree of such development attained in particular areas.

During that period, presumably of great length, when man did not know how to kindle a fire and when his tools, if any, were few in number and extremely crude, regions of dense forest must have been difficult of utilization and only their margins capable of effective occupancy. Obviously, this statement is based upon incomplete information, for our knowledge of such remote times is too fragmentary to permit much more than intelligent speculation concerning them. Nevertheless, in view of his inherited limitations, it would appear probable that man's earliest home must have been marginal to rather than in the heart of forests such as those of the rainy tropics, though doubtless he made use of certain of their products even then. During this period, then, dense forests were in a marked degree hostile rather than friendly to the primitive populations of that time.

Somewhat later, when tools attained greater perfection and specialization, the value of forests and their utilization increased, for they not only supplied nuts, fruits, and other foods, but clothing was fashioned from some of their products; their wood served as fuel and for building material; and dugouts, made from the hollowed-out trunks of trees, were used to transport man and his limited possessions from place to place. These values of the forest, like those of the preceding period, when its function was largely restrictive, must also have persisted for many centuries, during which human progress was slow.

When man began to cultivate crops rather than depend entirely on the bounty of wild life, plant and animal, the value of the forests altered once more among those populations which practiced agriculture. Then they were again a hindrance to occupancy, for forest cover must be removed, at least in part, before production of cultivated crops is a possibility. At that early stage of man's development, this was difficult, for tools were still few in number and not effective for use in clearing forest, so that hacking down trees with them must have been both laborious and time-consuming. In some areas of very heavy growth, such clearing may well have been virtually impossible, even when supplemented by use of fire. It is probable, therefore, that man's first attempts at agriculture were confined to areas of scattered tree growth, or even grasslands, especially since some of the first cultivated crops such as wheat and barley were developed from wild ancestors native to the steppes. Certainly, even as late as that period when the important civilizations of the Western world were grouped around the borders of the Mediterranean, there were no comparable developments in densely forested regions. Further, at that time there was widespread belief, even in well-informed circles, that no high degree of development could ever be attained in the heavily forested areas of either the higher or the lower latitudes because of the hampering effects of the vegetation cover, often associated as well with climatic and drainage conditions regarded as repressive for man, though favorable for tree growth. During this same period, however, the forests still supplied many of man's needs, including fuel and material for construction. In fact, so important were they,

even at that early time, and so extensive were the drains on their limited resources, that they were depleted seriously in the areas of early development around the Mediterranean.

As man made additional progress, he became increasingly able to cope with forest conditions effectively and, eventually, to an extent that the denser forests of northwestern Europe were subdued and much of the land formerly occupied by them passed under the plow. From Europe, man pushed across the Atlantic to the shores of the Americas and, in the United States, into the interior west of the Appalachians in considerable numbers. There, he cut down the trees, plowed the land, and planted crops. To these early settlers, the forest was boundless in extent and its wealth was inexhaustible. What timber they could not use for building houses and fences or for fuel was destroyed for, until this was accomplished, they could not plant crops. Therefore there was a profligate use of timber, unavoidable at the stage of development of the area.

Such clearing is no longer the general practice in the United States, since an adequate market for lumber and other forest products now exists. Further, it is now realized that there is a desirable balance between pasture land, crop land, forest land, and types of land devoted to other uses, for each satisfies some requirements; and that, unless such a balance is maintained, effective use of all is handicapped. Today, therefore, we no longer commonly destroy felled trees but convert them into lumber, and use of forests for the primary purpose of securing their products is in general an end in itself rather than a necessary step in bringing land into agricultural or some other type of effective production.

However, despite this evolution, all types of forest use which have been described still persist, much as do the various types of grazing, agriculture, and other human activities. In our consideration of forests and forest production, we shall, therefore, recognize the following present types of forest use: (1) the collecting stage, much like that of the prehistoric past; (2) clearing for agricultural use; and (3) various types of lumbering operations and the *harvest* of forest products.

The Collecting Stage. So long as man remained a self-sufficient hunter, he utilized only a small fraction of the possibilities offered by the forests. In this stage of his development, he modified the forest environment of areas he occupied but slightly, if at all, for the toll he took was small. Plants provided part of his food, it is true, but he was content with their fruits and a few of their other structures, and always his levy was so slight that few if any species were extirpated by his demands. Similarly, he depended on animal life, but his destruction of limited numbers of certain species which afforded food was offset by an accompanying elimination of the carnivora which preyed on them, so that the balance of nature was disturbed to only a negligible extent.

When Europeans first landed in North America, therefore, even though some of the Indian tribes had advanced beyond the primitive collecting stage of development and had become cultivators of the soil, they found the natural environment relatively unaltered, though probably not the primeval wilderness pictured by certain historians. With their coming, however, the collecting stage entered another phase: that of plundering the forest, not to satisfy the needs of a native population only, but those of more advanced groups in other parts of the world as well.

This is in general the phase of the collecting stage today in most parts of the world where it still exists, for example, in the areas of coniferous forest of Canada and Eurasia, and of evergreen hardwood forest in low latitudes. Today, the primitive populations of these regions enter into the world's economy by collecting products desired by more advanced populations of other parts of the world. Thus the Indians of northern Canada have become in large part trappers, working for the Hudson Bay Company, and dependent on exchange of furs to obtain the necessities formerly supplied from local resources. Wild rubber, tropical nuts, cabinet woods, and other products are secured from the forests of the low latitudes in somewhat similar fashion. Whether this exploitation affects the forest resources adversely to an important extent varies from place to place, and from time to time in the same place, though the change produced is always greater than that resulting from meeting the needs of a primitive hunting population only.

Clearing for Agricultural Use. With invasion of areas of denser forest growth by agriculture, removal of the forest cover is a necessary preliminary to growing cultivated crops. Among primitive populations of the rainy low latitudes,

continuous and rapid leaching, or loss of soluble mineral plant nutrients from the relatively infertile soils, limits continuous agricultural use of any clearing by native populations to a few years, and enforces frequent shifts of the fields under cultivation. This necessity for continuously bringing new land into production results in serious devastation of the forest and replacement of the original cover by jungle weeds or useless growths in the abandoned clearings. Thus such production in the rainy low latitudes leads to neither effective use of the forest resources nor permanently productive agricultural use of the land cleared. Even in those regions where population is so sparse that actual shifts of the villages are unnecessary, successive clearing, planting, and abandonment of the fields, made necessary by rapid exhaustion of the available plant nutrients in the ashes of the burning and the soils, produce the same effects, insofar as the forest and its composition are concerned. Primitive agricultural populations such as the Fang and the Djuka, it is true, make limited demands on certain forest products to satisfy some of their needs and thus use that portion of the forest resource effectively. Of late, however, they have exploited several of these products for barter, too often unwisely, so that the total of the destruction that has been wrought, both earlier and of late, has more than offset the compensating benefits accruing from either the agricultural or forest yields obtained.

Somewhat the same ineffective and wasteful utilization of forests was the prevalent practice during the Colonial period in the United States, notably in the Coastal Plain of Virginia. There the common cash crop, tobacco, grown on the prevailingly light sandy soils without the use of fertilizers, soon exhausted the supply of mineral plant nutrients, so that yields thereafter became too small to make profitable production of the crop possible. At first, this loss of cultivable area with such a "robber economy" was not generally considered any cause for alarm, since population was small, and land was abundant and cheap, though even at an early date some realized that eventual disaster must result. Nevertheless, when a field became unproductive, it was abandoned and another was cleared and planted. The abandoned field then reverted to scrub growth. This was much the same practice as that in some of the tropical forests today, where primitive tribes practice migratory agriculture. At last, however, the forested land of the coastal plain of Virginia was exhausted; none remained to be cleared and tobacco production became unprofitable on the ravished soils of the gullied fields. This led to abandonment of much of the land, poor living conditions among the remaining inhabitants, and impoverishment of the area. Even today, in some of the areas of earliest colonial settlement in the United States, much of the land is idle or grown up in virtually worthless brush and small trees.

When settlement later pushed west of the Appalachians into the dissected, hilly Allegheny Cumberland Plateau, and farther west to the flatter lands of the Mississippi Valley, much of the early clearing was still primarily to permit agricultural use of the land, though not necessarily with a view to its abandonment after a few years, and the timber, for which there was but limited use and no market, was destroyed to accomplish the objective of preparing the land for cultivation. Today, this seems a reckless waste of a valuable resource, but it should be remembered that, at the time and in the areas of early settlement, this waste was unavoidable.

It has in fact been true, not only in our own country but elsewhere as well, that, when clearing has been primarily with a view to making agriculture possible, there has often necessarily been a great destruction of forest resources. That this was frequently unavoidable furnishes cause for regret, since today the need for this wealth is brought home by high prices for lumber and the use of substitutes, some of lesser desirability than the forest products they have displaced.

Lumbering and Other Forest Industries. Where utilization of the forest is primarily for the purpose of securing lumber or other forest products, the land may or may not thereafter pass into agricultural use, dependent on a number of factors including location, topography, soils, climate, and others. Such lumbering operations or other forest industries may occur in several types of forest. Some are evergreen hardwood; others are deciduous hardwood; still others are coniferous in type. Areas of deciduous forest in intermediate latitudes commonly pass into agricultural use after clearing, irrespective of the objective in removing the timber; those of coniferous forest more often tend to remain in tree growth of some type, except where population is dense and pressure on the land is considerable. In harvesting the forest production, either lumber

or some other commodity, the method adopted may be of the migratory, exploitive type, or it may involve treatment of the forest growth as a crop which affords continued yields.

Migratory Lumbering. This is a pioneer type of lumbering, similar in its practices to those of much of the earlier pioneer agricultural use of the land. When this type of exploitation occurs, the life of the industry is short, for the objective is to obtain the maximum return in the shortest period of time, with no expectation of securing any future profit, except possibly from the sale of cutover land to prospective farmers. Too often, however, the attempts to use such land for the production of crops prove unprofitable and the area becomes an agricultural slum. No commercial forest remains; agriculture is unsuccessful; community services are inadequate and local resources will not permit their betterment; living conditions are poor and tend to become poorer. These are the common conditions in a large fraction of the cutover lands of the United States, particularly of those formerly in coniferous forest. Where the land does not pass into agricultural or attempted agricultural use, or such use proves unprofitable, the base for the regional economy narrows or even disappears with the passing of lumbering operations. Boom towns fade when the mills cease operations; houses stand vacant when employment vanishes; stores and hotels no longer have sufficient business to continue existence; and another "ghost town" is added to the lengthening list of formerly flourishing communities. This type of lumbering operation, or forest devastation, characterized most of the earlier attempts to exploit our forest resources for private gain. The period of its existence, however, was one of cheap lumber, for, until cutting improved its value, timber was practically unsalable. It was this supply of cheap lumber which in part made settlement of the grasslands of the interior of the United States a possibility, for it alone placed building material within the means of the pioneers of the prairies and steppes of the interior.

Lumbering by Harvest of a Forest Crop. The alternative to the migratory or exploitive type of lumbering is to treat the forest growth as a crop, allowing the young trees to mature before cutting, harvesting only those which are ripe, before deterioration sets in. Such a practice insures continuous, uninterrupted yields and a steady income from the forest industries and their products. Under such practice, the boom times associated with exploitive lumbering may be lacking and returns may temporarily be lower, but the abandonment and depression which follow destructive exploitation of the forest resource are likewise absent, and continued profitable use and returns become a possibility. Such a use of the forest was obviously impossible at an earlier date and, though desirable from the standpoint of the country as a whole, may be economically impracticable even today for the private individual, since lumber prices and confiscatory taxation frequently force undesirable cutting to prevent total loss of equity by the owner. In areas of older settlement like Europe, however, where experience has emphasized the necessity for effective use of all types of land, including those suitable only for a forest crop, the use of forest land to permit continuous though smaller returns is common under government ownership, and generally encouraged by laws which permit its practice by individuals.

Forest Industries of the Tropics. The forests of the tropics, though extensive and containing great reserves of timber, are virtually untouched by lumbering operations as yet, except as they supply a few cabinet or other woods of special but limited uses. In fact, more lumber from intermediate latitudes is shipped into the tropics than moves in the reverse direction.

Some of these tropical woods, however, though cut in only small quantity, are important, and some have been known and used for a long time because of their special properties. The black heartwood of ebony, for example, obtained from several species of trees and used for inlays and other cabinet work, is mentioned in Ezekiel xxvii:15 as a common article of commerce from Tyre. It was also known to Herodotus, who states that the Ethiopians sent 200 logs every 3 years as tribute to Persia. It was likewise known to the Romans, for it is mentioned by both Virgil and Pliny. Because so hard and black, early tradition taught that it was the wood of a tree never exposed to the sun and without leaves or fruit, though of course this is not true. Today, it is obtained from southeastern Asia and western equatorial Africa, where native populations, including the Fang, exploit the wild forest resource. Other common tropical hardwoods of value include mahogany and rosewood. The former is obtained

from Caribbean areas, Africa, and southeastern Asia; the latter from Brazil, Honduras, and Jamaica. Sandalwood, known since the fifth century B.C., and valuable because of its aroma, is likewise cut and marketed in small quantities. The most important of all the tropical hardwoods, however, is probably teak, obtained from the deciduous forests of those areas of southeastern Asia with rainfalls of 30 to 50 inches, and, of late, in small quantities from Central America. The tree, which grows best on well-drained slopes, attains a maximum height of 100 to 150 feet and a size of 24 inches in trunk diameter at shoulder height in 80 years, when grown on plantations. In the forest, growth is somewhat less rapid. The particular value of teak is its durability, perfectly preserved timbers 1000 years old being known. Therefore it is used extensively in India and adjacent areas in large buildings such as temples. It also possesses the desirable characteristics of not checking, splitting, or shrinking after seasoning, and it is likewise easy to work and takes a beautiful polish. When green, it is heavier than water. Therefore, when cut in the forest, it is seasoned before being floated out. This is accomplished by girdling the tree, or cutting a ring around its base. This kills the tree and allows rapid and effective seasoning by exposure to sun and wind. Most of the teak of commerce comes from Burma, where it is exported through Rangoon.

The hardwood forests of the tropics have so far escaped exploitation to any great extent, except by native populations, because of an unfavorable climate and the scarcity of labor in areas of their occurrence. Further, many of the woods are so dense and heavy that they will not float. Therefore, in the absence of roads and rail lines, it is difficult to get the logs to market. The varied stand of the forest is also a hindrance to lumbering operations since there is no demand for many of the species. Hence clean cutting is not practicable and taking out single trees far from streams is virtually impossible. Again, even for those species for which a market exists, the demand is limited, for hardwood lumber is not used in general construction but only for the manufacture of furniture, for interior trim, and for similar purposes. As a result of this combination of handicaps to profitable cutting, the tropical forests, particularly those of the rainy tropics, have so far been of but slight value to man as a source of lumber.

Forest Industries of Intermediate Latitudes. By contract with those of the tropics, the forests of intermediate latitudes at or near sea level are both hardwood and coniferous in type, or sometimes composed of mixed stands. The hardwood forests, made up of species which are for the most part deciduous, or which shed their leaves, consist of our common broad-leaved trees such as oak, hickory, beech, maple, walnut, elm, birch, and many others, including numerous shrubs. Some furnish lumber, used in the manufacture of furniture and for interior wood work in our houses; some of these same species, as well as others, are often used for firewood. The coniferous forests, the more important, include several valuable species of trees such as white, long- and short-leaf pine, Douglas fir, redwood, spruce, and cedar. Some are valuable for construction, others for the manufacture of wood pulp and paper, and several find some use as fuel.

Forest Industries in the United States. Hardly had settlers landed on the Atlantic seaboard before they began to despoil the forest, at first largely to clear the land for cultivation, but shortly to secure lumber for local use and timber for export, since the tall, straight pines of New England made excellent masts and spars for English shipping. Up to 1850, New England led in lumbering, with white pine the most valuable of the lumber produced. Even before that date, however, operations had extended to the west and south, this movement continuing to the present time at an accelerated rate, until cutting has today invaded the last important stand of virgin timber, that of the Pacific Northwest, where removal of the forest now proceeds at a rapid rate. Between 1850 and 1870 the center of production had shifted to New York and Pennsylvania; then it moved to the Lake States. By 1900, it was centered in the South and, since 1915, the most important cutting has been in Washington and Oregon, though lumbering still remains important in the southeastern states.

Forest Industries of the Northeastern United States. The United States uses two-fifths of the world's production of wood and one-half of that of wood pulp. Of this amount of pulpwood, the formerly extensive forests of the northeastern states supply only a small fraction; of the saw timber, even less. White pine, perhaps the best construction timber the world has ever known, is virtually exhausted except for scattered growths,

FIG. 324. *Top:* A worker piling spruce pulpwood, Superior National Forest, northeastern Minnesota. Paid at the rate of \$5.00 per cord for swamping out skidway, cutting trees, bucking, peeling, and stacking, he averages slightly less than one cord per day.

Middle: Hauling hemlock tie cuts by caterpillar tractor. Three miles north of Radisson, central Sawyer County, northern Wisconsin.

Bottom: Driving the Littlefork River, Koochiching County, northern Minnesota. The logs have jammed or lodged and the attempt is being made to free them so they will float down the Rainy River to International Falls, an important mill town on the International Boundary. The smaller logs will be used for pulp; the larger ones will be sawed into lumber. (Courtesy of the U. S. Forest Service.)

often of inferior quality, the bulk of the remaining timber being spruce and hemlock. These are cut for pulp, to be used in the manufacture of paper. This part of the United States has many advantages for such manufacture since the species of trees which grow in New England afford the necessary raw material, there is an adequate supply of clear water, and numerous swift-flowing streams permit development of the power necessary for use in the industry.

Forest Industries of the Lake States. Like the New England States, the Lake States have been denuded of most of their saw timber, both coniferous and hardwood, so that the forest production of importance today is not lumber but pulpwood. Some pine is cut, it is true, but the stands are limited, scattered, and often relatively inaccessible, so that only the great desirability of white pine lumber tempts lumbering operations. Most of the present cut of the conifers, and some of that of the hardwoods, is for cordwood, to be used in the manufacture of pulp and paper, and even that is limited. Of the area cleared, most of that formerly in hardwood forest has passed under the plow; of that in coniferous forest, a large part remains idle. Much of this is today tax delinquent and reverting to public ownership for non-payment of taxes. Some is absorbed in national forest;

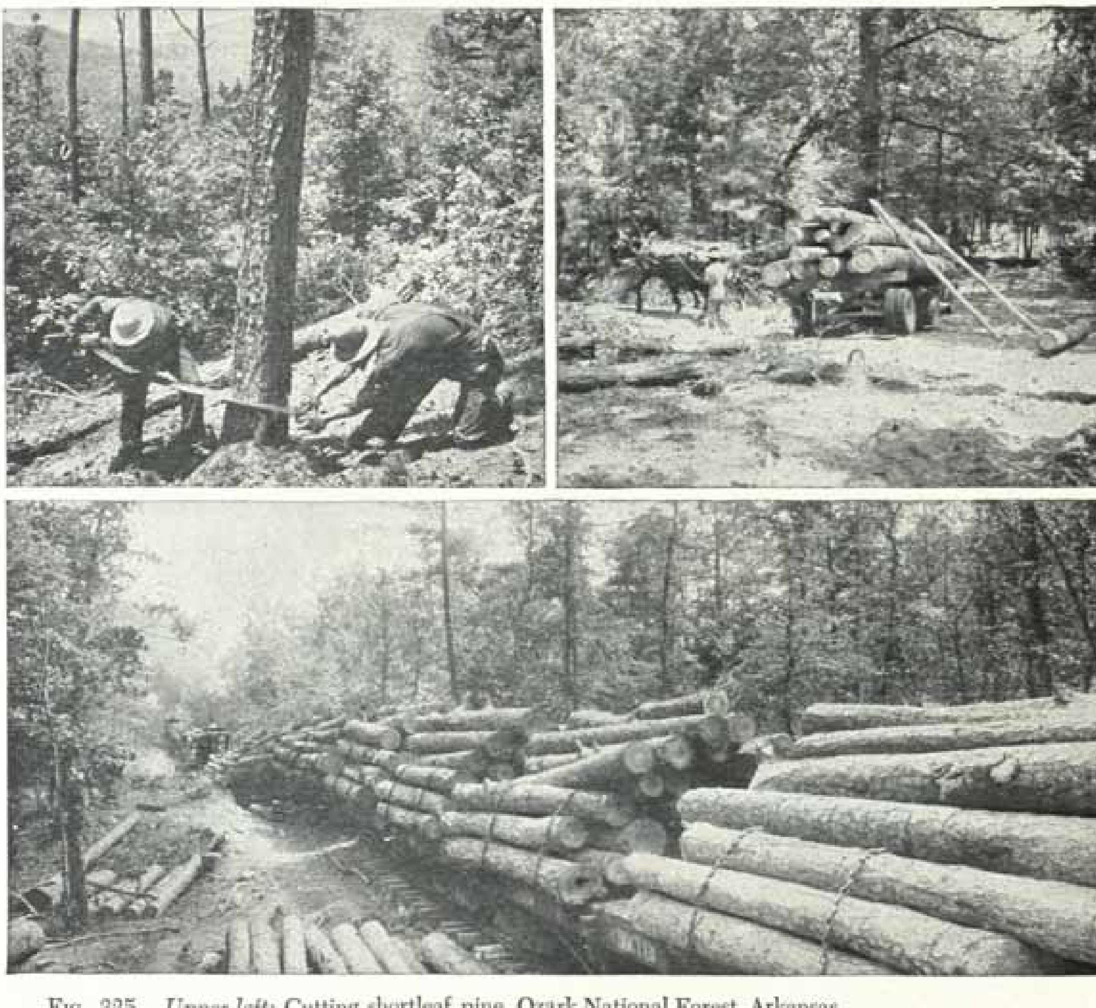

FIG. 325. *Upper left:* Cutting shortleaf pine, Ozark National Forest, Arkansas.
Upper Right: Loading a truck by a mule team and crosshaul, Davy Crockett National Forest, Texas.
Bottom: Loaded log train, Caddo River Lumber Company, Ouachita National Forest, Arkansas. (Courtesy of the U. S. Forest Service.)

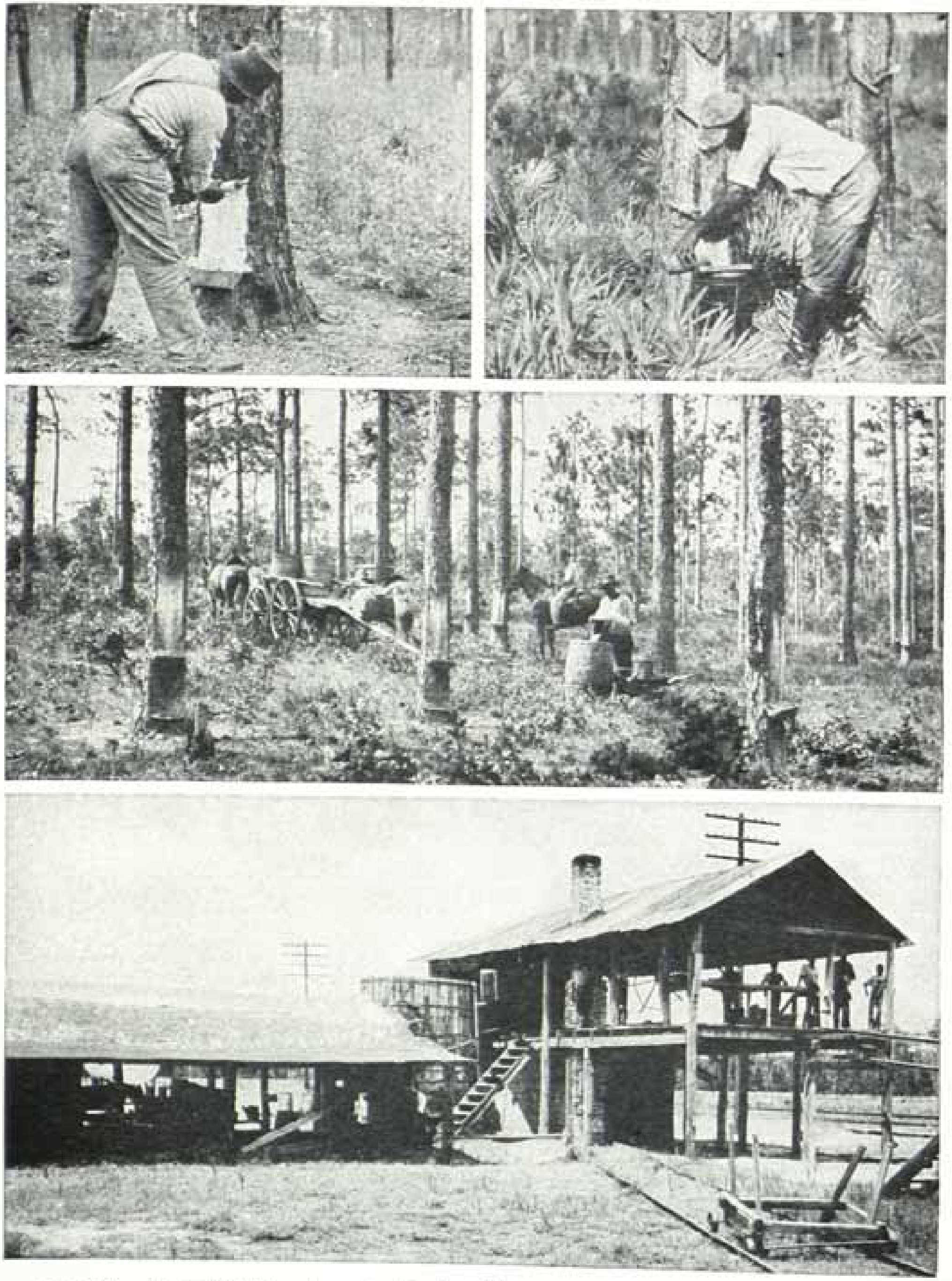

FIG. 326. *Upper left:* Preparing a tree for the collection of turpentine, putting on the "first streak," Choctawhatchee National Forest, Florida.

Upper right: Pouring gum from cup into hand barrel, Osceola National Forest, Florida.

Middle: Gathering the take of the "dip squad," the collectors, in large barrels, Ocala National Forest, Florida.

Bottom: Turpentine distillery, Osceola National Forest, Florida. (Courtesy of the U. S. Forest Service.)

some is added to the areas in state forest. In either case, it is removed from the tax rolls and the local tax base is narrowed, often to the point of danger. Further, employment disappears and the basis for support of the population is destroyed. The problems introduced by large areas of cut-over land become especially serious in those counties formerly covered by coniferous forest, where an entire county may lie within the limits of public forests which yield little or no revenue to the local community.

Forest Industries of the Southeastern States. Except for prairie and marsh land, most of the surface of the southeastern states originally had a forest cover, either hardwood or coniferous. The hardwoods, characteristic of the rough country of the Appalachians and the Cumberland Plateau, and of the alluvial plains of the Mississippi and its tributaries, were oaks, hickory, walnut, cherry, gum, yellow poplar, and other valuable species. The conifers were pines of various kinds on the uplands and cypress in the swamps. Originally covering nearly 300,000,000 acres, the commercial timber, even including cordwood, now covers only about one-third of that area. In this forested region, fires—many set deliberately to improve pasturage—grazing, and the rooting of razor-back hogs, all conspire to keep natural reproduction low.

Much of the cut of this region is lumber, both hardwood and softwood, this source supplying most of the demand of the area east of Chicago

FIG. 327. Caterpillar tractor operating in a Puget Sound Douglas fir, spruce, and hemlock forest, near Hoquiam, Washington. (Courtesy of the Washington State Progress Commission.)

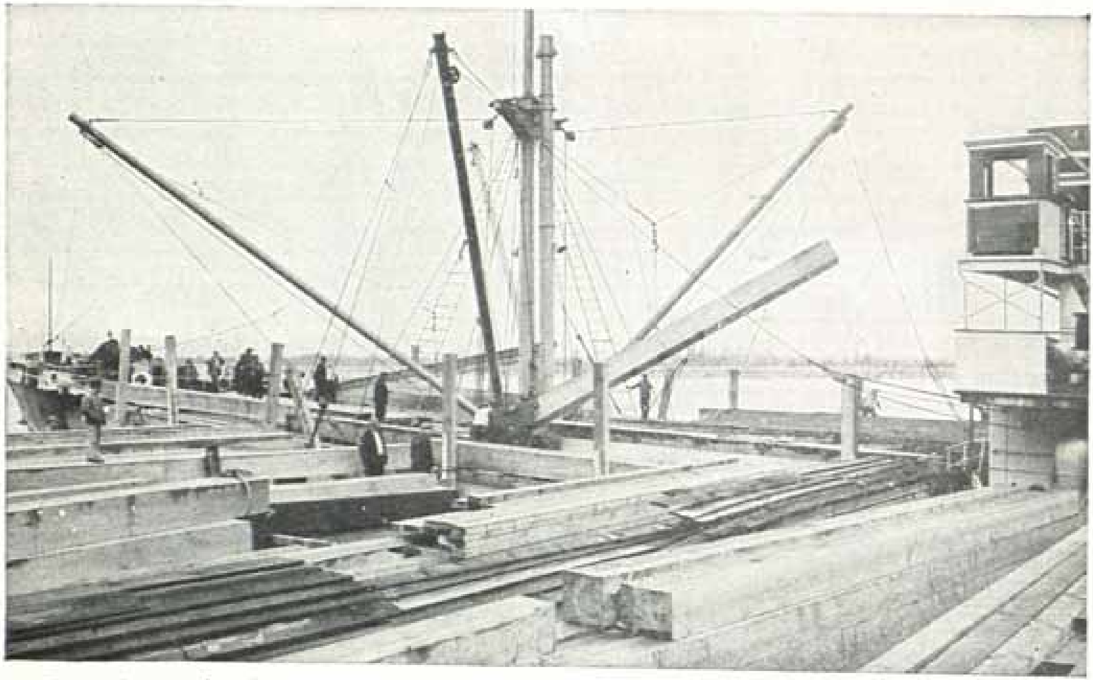

FIG. 328. Loading large-sized timbers by booms and tackle of the ship taking on the cargo, Portland, Oregon. (Courtesy of the U S. Forest Service.)

because of its accessibility to that market. In addition, there is an important production of naval stores: pitch, tar, and turpentine. These operations began in North Carolina, progressed into South Carolina, then into Georgia, and, still later, into Florida, the areas of earlier production decreasing in importance as the industry shifted south. Of late, as well, the manufacture of kraft paper, a tough, brown wrapping paper, has assumed importance, and recent developments indicate that, by appropriate treatment, the inferior loblolly or old-field pine can be used for making the better grades of paper. This will go far toward solving the problem of effective use of the cutover lands of the Southeast. This is particularly good news, for trees grow rapidly in this warm area and markets for the possible paper production are near by and easily accessible by rail.

Forest Industries of the Far West. The Pacific Northwest is a land of forests which contain the last important stands of virgin timber and more than half of the present saw-log reserve of the United States. Further, they are valuable forests of Douglas fir, redwood, pine, spruce, cedar, and hemlock. Many of the trees are of enormous size, even reaching such almost unbelievable dimensions as diameters of 15 to 20 feet and heights of 300 feet. They are so large, indeed, that lumbering operations are entirely different from those farther east and southeast. Much machinery is used in the removal of these forest giants. Formerly, donkey engines and draglines were employed but, of late, the caterpillar tractor, which causes less damage to young growth, has been used extensively to haul the logs to trucks or rail lines which transport them to mills, where they are sawed, or to tidewater for rafting to mills some distance away. The mills, mostly situated at tidewater to ensure continuance of an adequate supply of logs, represent substantial investments and turn out enormous quantities of lumber. This is marketed in eastern United States, but mostly west of Chicago, and in other parts of the world, but particularly in the Orient.

Around such a milling center as Longview, Washington, a planned community located at the junction of the Columbia and Cowlitz rivers, and accessible from the sea by ocean-going vessels, a set of integrated wood-using industries, designed to use all parts of the logs to advantage, has developed. These include manufacture of

lumber, lath, wood pulp, slab fuel, fabricated products, and even production of power, developed by a wood-burning plant. To be profitable, it is necessary that such a group of industries have a continuous supply of raw material, even after exhaustion of the virgin timber. To afford this supply, replanting was undertaken, but this has been halted of late as a result of excessive taxation. Such a policy, it is true, produces temporarily greater returns to the public treasury, but the ensuing discouragement of reforestation, plus increased cutting, eventually destroy the tax base and cause bankruptcy. Where such excessive taxation is the practice, the community is living up its principal. The proper policy is to tax the land and the forest separately, the latter but once, when the tree crop is harvested. Under this practice, reforestation may pay and, if so, the tax return will continue undiminished and the community will remain solvent.

The Forest Mine of Canada. Of the slightly more than 1,250,000 square miles of forest land in Canada, about 30 per cent is estimated to have merchantable timber. Of this, 68 per cent is east and north of the Great Lakes; 18 per cent is in British Columbia. Much of this forest is not saw timber, for the trees are small, but the species are suitable for the manufacture of pulp, the production of which has developed as an important industry along the southern margin of the Laurentian Highland. The basis for this development has been the adequate timber resource, the available supply of clear water, the possibility for generation of power where the rivers drop over the edge of the highland to the plains which border the St. Lawrence River, and the expanding market for paper in near-by areas. This development is of interest to us since we obtain half of our newsprint from our neighbor to the north. On the West Coast, the forest is similar to that of of the Puget Sound region in the United States and lumbering is there, as on this side of the border, an important industry, supplying forest products, not only for the local market but for export as well, particularly to the Orient. The toll levied on these forests has been very heavy during recent years. The production of Sitka spruce, for example, has been up at least 50 per cent, because of its use in military planes. Already, the virgin growth is largely gone; all types of this timber will be exhausted within the next 40 or 50 years. The cutting of both spruce and fir is in stands which have required 250 years to grow and reforestation is not practiced because of governmental regulations with reference to leasing and cutting. These impose an annual tax of $140 per square mile of leased forest land, irrespective of whether any timber is cut. To hold the land under such regulations is to invite certain bankruptcy. Therefore the holder of a lease cuts the timber as rapidly as possible to decrease the amount of this tax. When the merchantable timber has been removed, he does not attempt reforestation but abandons the lease. Though this may be financially profitable for the individual, it is not in the public interest.

Forest Industries of South America. Despite the high percentage of its land surface in forest, estimated at 44 per cent, or more than 25 per cent of all the forest land in the world, even the most important areas producing forest products in South America are small, widely separated, and production is limited. This is because profitable operations in the tropical forests are difficult and confined to stream margins. Elsewhere, except in the southeast, valuable forests are lacking. The hardwood forests of the tropics furnish medicinal products, gums, resins, dyes, nuts, and limited amounts of hardwood lumber such as mahogany and rosewood, but the total value of this production is small. South of the 38th parallel in Chile, the rain-soaked forests, in which lumbering is carried on with dfficulty and for only part of the year, supply a limited quantity of saw timber, though larger amounts of poles, posts, firewood, and poor quality lumber for local consumption. Only in Southeastern Brazil is there an important stand of commercially valuable forest. There, Paraná pine, which grows to a diameter of 4 to 6 feet and to heights of 80 to 120 feet, covers approximately 100,000,000 acres, and there the only really important lumbering industry in South America has developed, the cut being exported as well as used locally. Yerba maté, or Paraguay tea, the leaf of a tree which when treated with boiling water produces a stimulating beverage, the favorite drink of several million people, is also obtained from this same general area.

Forest Industries of Africa. The forests of Africa are of even less commercial value than those of South America. In the south, there are none of importance; in the rainy tropics, their products are limited to nuts, some cabinet woods,

FIG. 329. Hauling logs in the Siberian taiga during the winter, with use of a caterpillar tractor. Erijsky lumber station, near Lake Baikal, Buriat-Mongol Autonomous S. S. R., (Courtesy of Sovfoto.)

and possibly some wild rubber. In many areas, in fact, the forest growths of value have been destroyed by native exploitation and cultivation. In the north, much of the land has been denuded of larger trees and even of all tree growth, particularly where pastoral pursuits have led to systematic firing to secure better grazing, or where crops have preempted the land. Thus today, for example, the greater part of the Moroccan Tell, the fertile land of the maritime border, is bare of forest. In the mountains, however, some still remains, made up of several oaks, from one of which cork is obtained; cedar; and Aleppo pine, the last two affording construction material. However, the value of these forests is slight and, except for cork, they furnish no products for export.

Forest Industries of Asia. It is estimated that 21.6 per cent of Asia is forested and, though this percentage is not large, the area is enormous because of the great size of the continent. Therefore these forests are among the largest in the world, though but little utilized as yet. In the southeast, teak is a valuable forest product, and the Philippines and certain other areas supply cabinet woods, but the total output from these low-latitude forests is small. In eastern Asia, in China, most of the original forest cover has been destroyed and forest production is unimportant. In Japan, much forest still remains in the mountains, particularly in the northern island, Hokkaido, where it forms the basis for a paper manufacturing industry. Some lumber is also produced in Japan, but it is mostly of inferior quality, since the species of trees available, except for one of the cedars, the *Cryptomeria*, do not afford good saw timber. The most important of the commercial forests of Asia are those of Siberia, the exact extent of which, though unknown, is vast. These lie to the south of the tundra and are not continuous. Pines, fir, spruce, larch, and cedar, all conifers, make up approximately 75 per cent of this forest; the balance consists of deciduous hardwoods. In places, the stand is pure; else-

where it is mixed in composition. Up to the present, these forests have been exploited but slightly because of the undeveloped character of the country and poor transportation facilities, but this condition is now altering rapidly.

Forest Industries of Europe. It is estimated that 33 per cent of Europe, largely areas of either thin and poor soils or rough topography, is forested, but primeval forest has practically vanished in this highly developed continent, and trees are grown largely as a crop. In the south, around the Mediterranean, the percentage of land in forest is small, and the same is true in the British Isles; in Ireland, it falls to 1.4 per cent. In most of continental Europe, it varies from 20 to 30 per cent; in Sweden, it rises to 54.8 per cent; and in Finland to nearly 65 per cent. In these last two areas, much of the country is rough or poorly drained and soils tend to be thin and poor, for both have been so heavily glaciated that stony soils and rock exposures are common, and drainage has been rejuvenated. In addition, the climate does not favor agriculture.

In these last two countries, therefore, the forest resources play a significant role in the economic life and serve as the basis for an important export trade. Even in Portugal, however, where the percentage of land in forest is small, cork is a valuable export, and, elsewhere as well, the forests are more important than might seem probable in this old and densely populated part of the world. In Finland, where approximately 65 per cent of the land is forested, with 40 per cent in first-class timber, the pulp and paper industry is highly developed and nearly 450 sawmills contribute to lumber production, so that forest products normally equal about 80 per cent of the total exports. In Sweden, likewise, with such a large percentage of the land in timber, the economic life of the country depends to an important extent on the timber and woodworking industries. In all, these afford employment for about 90,000 workers, and timber and wood products comprise nearly 50 per cent of all exports. These products from both Finland and Sweden find a ready market in western Europe, including the British Isles. Further, in both Finland and Sweden, an enlightened forest policy ensures permanence to the forest industries.

Our Forest: Mine or Crop. Most of the destruction of our forests has occurred during the past hundred years, for important cutting did not begin until subsequent to 1840, and the peak production of 47,000,000,000 board feet was not reached until 1907, the period of heaviest drain coinciding with that of agricultural invasion of the fertile, treeless grasslands of the interior, and construction of millions of frame buildings on their farms and in their cities. This drain on the forest has decreased since, with higher prices for lumber, increasing use of substitutes, and a less rapid growth of population. In 1932, the cut was only 10,000,000,000, and until recently it has not exceeded 30,000,000,000 board feet. Spurred by war and post-war needs, however, production has been much greater, the cut for 1947 being estimated at 35,000,000,000 board feet.

For many years, much of the cutover land passed into profitable agricultural use. So long as this occurred, though loss of the forest may be regrettable, the present more effective use of the land is preferable for, after all, land should be put to its best use, and growing trees in areas which can be used profitably for producing crops other than trees is not desirable.

Much of the more recent clearing, however, has been of poor agricultural land, particularly in areas of coniferous forest. Further, the acreage of cutover land has increased rapidly of late. Therefore it is obvious that the demand for such land for agricultural use is not pressing. Certainly the belief held by some that cutover land eventually passes into agricultural use is not substantiated by the facts.

That much of our present cutover land can best be used for growing a forest crop is indicated by the fact that the sale of such land for agricultural use is very slow, even when pushed vigorously. It was estimated, even in the 1920's, that, at the rate of absorption in Minnesota at that time, when it was being taken up more rapidly than at present, a century or more would be required for even the best of the cutover land to be occupied and that, in the Upper Peninsula of Michigan, 800 years would elapse before all such land would be absorbed in farms. This would at least suggest that agricultural opportunity is lacking in such cutover areas.

We have apparently at last come to the time when the forest should be managed as a crop, not as a "mine," much as has been the practice in the older, more progressive countries of Europe for many years. There, in Germany, France, and elsewhere, private and governmental forests,

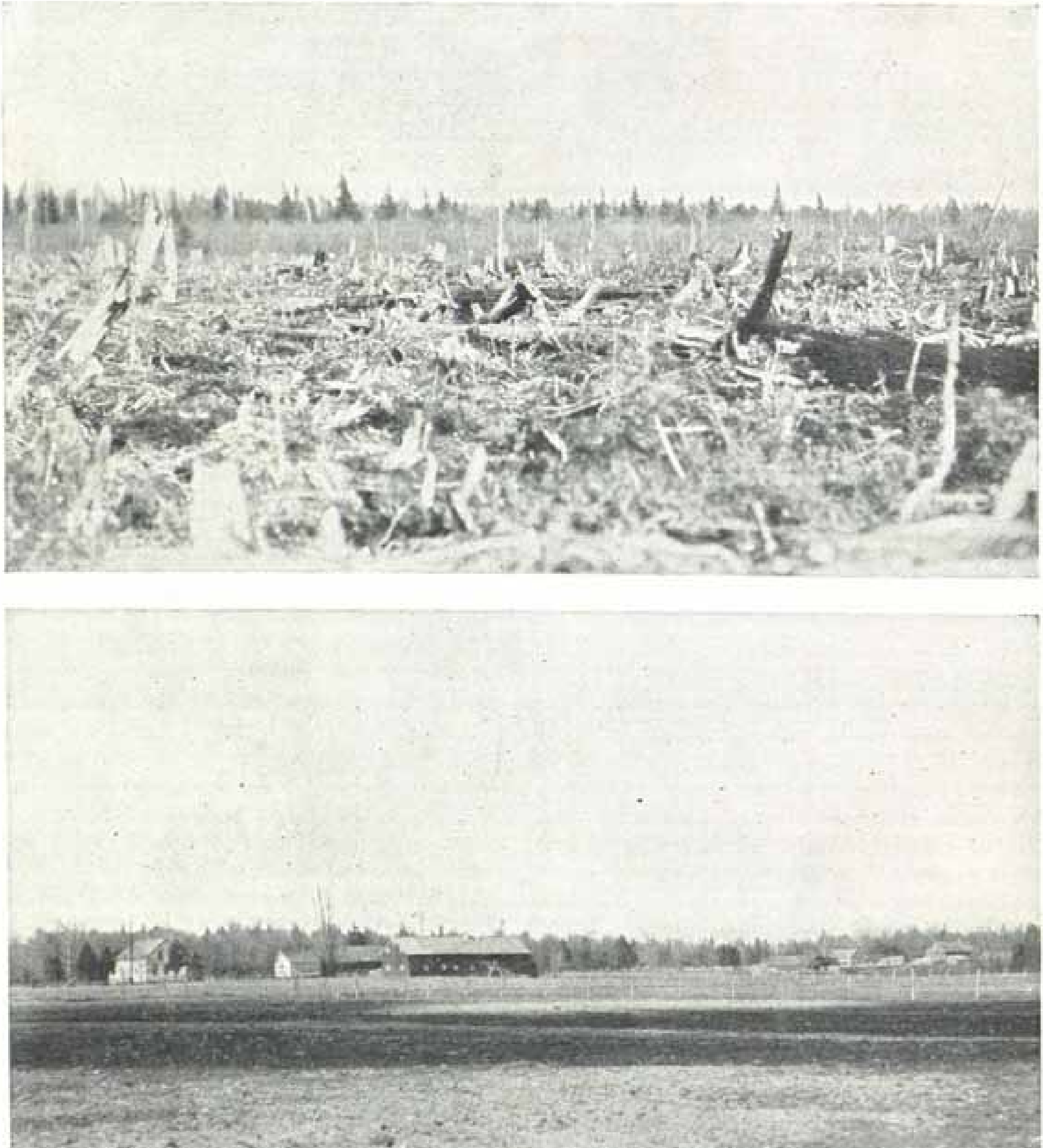

Fig. 330. *Top:* Cutover land on a farm in Menominee County, Upper Peninsula of Michigan, in the first stage of preparation for agricultural use.
Bottom: The results of 30 years of clearing on the same farm, one of low productivity.

located on nonagricultural land, serve not only to conserve moisture and check erosion, but they afford as well off-season employment, support woodworking industries, supply fuel and lumber for local use, shelter wild life, present recreational possibilities and, with all these, furnish excellent investment for funds, both private and public. Many farmers in the United States could likewise profitably utilize some of their poorer, less productive acres for growing timber rather than continue the common unremunerative practice of putting them in ordinary field crops. Such woodlots, indeed, would enable a satisfactory return from land now unproductive, and possibly contributing to erosion, as well as afford employment during the slack season.

Fortunately, there is now some appreciation of the necessity for a more intelligent policy than the one which prevailed at the beginning of the present century, when it was considered to be respectable to scalp the earth and glory in the deed, if it was done under the guise of "development." Such is the power of a phrase in lending respectability to an outrageous performance! This dawning realization of the importance of protecting what remains of our forest inheritance is evidenced by the rapid growth of national and state forests, the former alone now containing approximately one-third of all our standing saw timber, though much of this is located in rather inaccessible areas. Our state forests, unfortunately, generally have but little commercial timber, since they are often made up largely of cutover land which has reverted to public ownership through nonpayment of taxes.

This acquisition of land by the government is a step in the right direction, but another should be taken to make certain that forest land, that is, land best used for growing a tree crop, will be devoted to that purpose. To accomplish this, it will be necessary to hold forth inducement to individuals to invest money in growing timber. At present, we too commonly penalize such investments by confiscatory taxation. Such a policy forces unwise cutting to prevent complete loss and throws the subsequently worthless cutover land into state ownership. Punitive taxes on timber land, it is true, may temporarily yield a greater return, but over an extended period of time they produce less than would be secured by a fair assessment levied on the forest crop, not each year, but only when it is harvested.

QUESTIONS AND EXERCISES

1. How have the limiting effects of forests on man varied at different stages of his development? What was their effect during the period when early Western civilizations were centered around the Mediterranean? How did this affect evaluation of opportunity in other areas at that period of history?
2. What are the three stages of forest utilization? Do all exist at present? If so, name some area where each exists today. How is it possible that all three stages continue to exist at the present stage of man's development?
3. What change has the collecting stage of forest use undergone of late years? How has this affected the extent of forest modification produced? Has this change been beneficial or the opposite? In what respects?
4. What effect has clearing of tropical forests for agricultural use of the land had on areal desirability? How has clearing affected the economy of the coastal plain of Virginia? The present density of population as compared with that of the past?
5. Why is it inevitable that, when clearing is primarily for agricultural use, there will generally be a great waste of forest wealth? Under what conditions, if any, will the opposite be true?
6. In what different types of forest are lumbering and other forest industries carried on? In what respects do these types of forest differ from one another? Which is the most valuable of these types of forest? Why? For what do its woods find use?
7. What are some of the detrimental effects of migratory lumbering operations? Illustrate some of the aftereffects of such lumbering operations by citing those for some definite location, chosen from your own state if possible.
8. What is the alternative to migratory lumbering? What are its advantages? Name some area where lumbering is of this type.
9. To what extent are the forests of the tropics important today as a source of raw materials? What products do they supply? Why are they not exploited more extensively? Where are the products of such forests marketed?
10. Describe the shifts of lumbering operations in the United States from colonial days to the present. Where are lumbering operations important in the United States today?

11. Of what importance are the forests of New England today? Of the Lake States? What products do they supply? Where are these products marketed?
12. What is the extent of our southeastern forest? What products does it supply? Where is the lumber from these forests marketed? Why? What does the future hold for the forest industries in this area? What use of the resources of our southeastern forest has become of importance of late?
13. Where are the most important remaining commercial forests of the United States located? How large a fraction of the present forest resource do they contain? What products do they supply? Where are these marketed? Why is this a good area for forests? What is the handicap imposed by their location?
14. Describe the "forest mine" of Canada as to location, types of forest, and use. How rapidly is it being depleted? In what respect is governmental policy responsible for this depletion?
15. Describe the forests and forest industries of South America and Africa as to location, extent, and value of the production. What species of trees supply most of the lumber cut?
16. Describe the forests and forest industries of Eurasia. Compare those of Europe and Asia. Why are they more important in Europe at present? In what part of Asia are they assuming greater importance than in the past? How is the forest administered in Europe? Why are forests so important in Finland and Sweden? How have governmental planning and encouragement stimulated the forest industries in these areas?
17. When did the important drain on the forests of the United States begin? When did this drain reach its maximum? Why? Why has there been a decrease in use of forest products since that date? What effect did the war have on our forests? Why was a shrinkage of our original forest area inevitable and to our advantage? Under what conditions has deforestation been detrimental in the United States? What are some of the detrimental effects?
18. Outline an intelligent policy for forest use in the United States. Why may it be difficult to secure public support for such a plan?

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Chapter Thirty-Five

MINING

Mineral Wealth and Its Exploitable Occurrences. The solid crust of the earth has been undergoing modification for unknown thousands of years, generally so slow that it escapes ordinary observation, but sometimes so rapid at times of great natural catastrophes such as volcanic eruptions as to force attention. One by-product of this long process of change is the concentration of mineral wealth, often in accumulations of sufficient size and purity to be of economic importance. Some deposits, such as those of coal, petroleum, and natural gas, are of organic residues, altered by the same agencies which have changed the sediments in association with which these minerals occur. Others, like those of all the metals and most of the nonmetals, are of inorganic materials, though living organisms may have participated in the processes which make their deposits of value to man.

If widely disseminated through the rocks, economic recovery of a mineral is impracticable, but where concentration has occurred through the action of either organic or inorganic agencies, commercial exploitation is often possible. This concentration may result from simple evaporation and deposition from solution; again it may be produced by precipitation with change of pressure or chemical condition in the solvent, either with or without the intervention of organic agencies. Often, it accompanies cooling of molten material as a progressive separation of various economic minerals in deposits of commercial importance. Valuable occurrences may even be formed in loose material by mechanical sorting on the basis of differences in specific gravity, for example, of gold in alluvial gravels.

Sometimes these processes occur at or near the surface of the earth; at other times, they take place at considerable depths, which may be so great that existence of a mineral deposit is unsuspected for long periods of time. Such deep deposits, even if known, are difficult to work, which decreases their value materially. Often, however, nature cooperates by the the slow operation of the agencies of disintegration and erosion to reveal many formed at great depths. Thus the "roots" of once lofty mountains may come to form the actual land surface, with the secrets of their formerly buried layers bared for the benefit of man. Further, the material worn from these same highlands is transported, redeposited, and some of its mineral wealth may be concentrated in unconsolidated sediments from which it can be extracted economically.

Mineral Deposits and Their Volume. Deposits of minerals, both metallic and nonmetallic, differ greatly in the frequency and extent of their occurrences. Some, like those of coal and iron, are found in many places and often in enormous quantities; others, such as those of tin, are known in but few localities and the deposits are definitely limited in quantity. Fortunately for man, those which are most indispensable and necessary in large amounts are present in those same quantities, and of those needed in relatively small amounts the resources are adequate for some time to come, if used intelligently. It is possible, of course, that certain of the rarer metallic minerals would find more extensive use if they were of more widespread and important occurrence, though this is by no means certain for all. It is doubtful, for example, whether any great addition to the world's supply of gold would have definitely beneficial effects. On the other hand, if platinum were available in greater quantities, it might well be that its use would be greater. In general, however, man has no valid reason to complain of the bounty of nature in respect to his

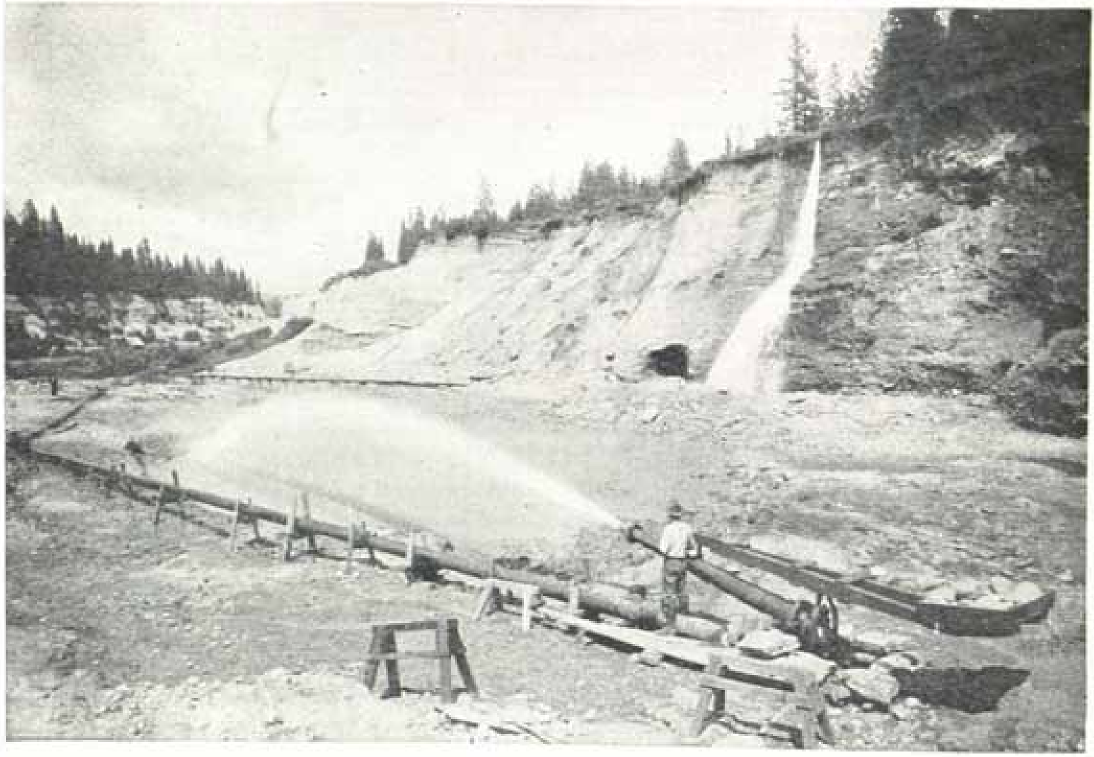


FIG. 331. Washing cycle in a typical hydraulic gold mine, where alluvial gravels are worked. Camptonville, eastern Yuba County, on the Yuba River, which rises on the western slope of the Sierras of northern California. (Courtesy of the U. S. Bureau of Mines.)

heritage of mineral wealth and this is particularly true as regards the mineral inheritance of the United States.

Mining an Exploitive Industry. Today we are robbing the accumulations of centuries in our mining operations. Thus mining is very different from most other economic activities. When man, for example, lives by hunting and fishing, he leaves some of the life forms which furnish his food supply to reproduce their kind; when he levels the forests, trees will spring up again if given an opportunity; when he takes crops from cultivated fields, others can later be grown on the same land. But when he extracts the mineral wealth, there is no possibility of its replacement within the probable lifetime of the human race. Thus when we have pumped all our petroleum and mined all our coal, we shall be forced to seek other means of generating heat and developing power; when we have taken out all our iron ore and smelted it, some substitute for iron must be found. With exhaustion of other minerals, we shall likewise be forced to seek materials to serve in their stead or suffer deprivation, if this proves impossible. We should, therefore, use our heritage of the minerals judiciously so that the coming of the day when their exhaustion will occur may be deferred as long as possible.

Exhaustion of Mineral Wealth and Some of the Effects. Not only will eventual dissipation of existing known resources of the minerals force use of substitutes, but it will also have far-reaching effects on the material welfare of many communities. In those where mining is the only basis for present support, it may cause extinguishment of occupancy; in others, where manufactures involve processing of minerals or fabrication of mineral products, it will at least alter the character of the industrial development and may produce even more fundamental change. Even where the effect will not be so direct, it will be important, for all human societies today use minerals for one purpose or another. Thus, even hunters and fishermen will be affected, and farm-

ers to a much greater extent, but particularly those dependent, even indirectly, on the complex industrial development of Western civilization.

The Importance of Minerals and Mining. Important mining of minerals is deferred until rather late in the stages of human progress. This may be partly because of man's preoccupation with the problems of providing for such vital needs as food, clothing, and shelter during the earlier periods of his development. These may be satisfied, though rather inadequately, without any "mining" of minerals and, quite effectively, without their extensive use. Again, the value of many minerals to man is not always obvious, for often they do not occur in such form that they are capable of use without at least some preliminary treatment, and few of those of greatest utility exist in a pure or uncombined form to any important extent, if at all. Often, as well, the deposits are not easily discovered, or the form in which the mineral occurs may be one not familiar as a source of the particular metal or nonmetal.

Man's mining and use of minerals have thus been limited by the stage of his advancement and his dependence on them has increased consistently as new uses for some have developed and uses for others have been discovered. This particular aspect of minerals and their value as a factor of the environment have been considered in Chap. XXIV. At this point, therefore, it is sufficient to restate that, with the passage of the years and progress in human development, mining of minerals has increased greatly in importance in the more highly developed areas and in those where penetration by more advanced populations has occurred.

Human Culture and Mining. The culture of a population group is often the decisive factor in fixing the character of the economic activities of an area. Thus it does not necessarily follow that mining will be an important occupation in all areas where mineral wealth is abundant nor that mining will not be of some importance in others of lesser natural opportunity. In China, for example, deposits of high-grade coal are widely distributed and the tonnages available are enormous. Yet for thousands of years but little local use was made of this valuable mineral, except for the smelting of small quantities of iron ore. Even in North China, where coal occurs widely distributed in beds of great extent and thickness, and where winters are both long and bitterly cold, and trees are few in number, it is still used to only a limited extent as fuel. In this agricultural region where attachment to the land is great, the peasants apparently prefer to cultivate the soil rather than disturb the earth by burrowing in its bowels. Instead of burning coal, therefore, they make use of limited crop wastes and laboriously gathered faggots, protecting themselves from the low temperatures of their inadequately heated houses by swathing their bodies in layers of wadded cotton clothing. By contrast, western Europeans, with a different culture, have used more limited and often less desirable resources of coal effectively in both homes and factories for many years. Thus we have today various stages of dependence on minerals, as influenced by different cultures coincident in time, which afford a fairly complete picture of the evolution of their use by man.

Mining and Occupancy of Regions. One result of the increasing importance of minerals is that the search for new deposits has carried man into unexplored regions and added materially to knowledge of the earth's surface. Further, civilized man establishes settlements wherever discovery of gold or other precious metals occurs, even in the driest of deserts or the frozen wastes of the higher latitudes, though he must import his food, clothing, building material, and possibly even his water. This is indeed a great change from the earliest of times, when such areas were shunned, except as compulsion forced their occupancy.

Relative Importance of Mining as an Economic Activity. The relative importance of mining varies not only with the culture of a population group but as well with whether areal opportunity is diverse or limited. Where diverse, mining is often of subordinate importance, even though commercial deposits of mineral wealth are known and worked rather extensively. In a state such as Illinois, for example, though the value of the annual mineral output is approximately \$200,000,000, mining is an economic activity of only secondary importance, being overshadowed by others such as agriculture, industry, and trade. In all, this activity, mining, affords employment to less than 1 per cent of the state's population. Therefore, though actually of great importance in Illinois, its relative importance is so slight that its role as a contributor to the state's prosperity may easily be overlooked. Certainly, the average

person seldom thinks of Illinois as a mining state.

By contrast, the state of Nevada is one relatively limited natural opportunity, which restricts man's choice of profitable occupations. Climate prevents effective agriculture without irrigation, and the amount of water available is too small to make it possible to bring more than a small percentage of the land into production. Even the opportunity for grazing is slight, for much of the state is desertlike or even true desert, and pasturage is almost everywhere poor. These handicaps to both agriculture and grazing prevent their supporting any considerable population in this most sparsely populated state in the United States. Under such circumstances, though the value of the annual mineral production is only about $25,000,000, less than 14 per cent of that of Illinois, the relative importance of mining is great because other occupations afford such limited opportunity that approximately 5 per cent of the state's population turn to that industry for employment. Therefore the average person thinks of Nevada as an important mining state.

Effects of Position and Physical Conditions of the Deposit on Mining. Whether a given mineral deposit is of economic value depends not only upon its size and degree of concentration, but also upon its relation to the strata with which it is associated. If the amount of overburden or overlying material is small, mining by stripping or removal of the overburden may be possible; if the deposit is more deeply buried, a shaft must be sunk. This adds to the costs of production. Again, if the beds, for example of coal, are very thick and it is necessary to mine them by underground operations, it may be difficult to secure adequate support for the roofs of the necessary horizontal openings or drifts into the deposit. Other factors which are likewise often important include the extent of fracturing of the seams; the number of breaks in their continuity resulting from faulting or slipping of the strata along lines of weakness; and the amount of water which must be pumped to keep the mine dry and permit its working. Thus, in some of the coal fields of China, thickness of the seams is too great for easy mining; in others, the coal has been badly crushed or shattered by crustal movement; and many seams are discontinuous because of faulting. Elsewhere, the mines are wet, necessitating much pumping and the burning of coal for that purpose. These

FIG. 332. *Top:* Strip-mining of coal in Pike County, southwestern Indiana. In this procedure, the coal is worked with steam shovels, which transfer two yards at a time into the cars, run into the open pit or mine on tracks. (Courtesy of the U. S. Bureau of Mines.)

conditions decrease the value of such deposits, since they interfere with operations and increase the costs of production.

Effects of Location on Mining. Even though a deposit is large and of high grade, and physical conditions are favorable for mining, it often cannot be developed profitably because of lack of satisfactory transportation, or because of its great distance from existing or potential markets. This is particularly true for the bulkier minerals, or those of low value per ton, but not for others such as gold, silver, and platinum, which are of such high value per pound that transportation charges are of lesser importance.

Gold Mining in Alaska. Mining in Alaska furnishes many excellent illustrations of the fact that lack of good transportation does not prevent exploitation of rich deposits of the precious metals such as gold. In some of the operations near Valdez, for example, the only access to the workings by land is by dangerous and difficult trails over which it is impossible to move machinery except by pack horses, and at excessive costs ranging from 20 to 35 cents a pound. Therefore airplanes have been pressed into service but, though costs of such transportation are high, the value of the product, gold, is so great that profitable production is possible. Even with its present inadequate transportation system, Alaska produced $23,170,000 worth of gold in 1938, nearly 90 per cent of the total mineral production of the territory in that year. Coal production, by contrast, comprised only 3.2 per cent of the value of all, about half of that of the small output of platinum ores, not of common occurrence.

Alaska likewise affords numerous excellent examples of the fate which overtakes towns, once the valuable mineral resource which supports them has been exhausted. Before discovery of gold in the Klondike in 1896, for example, the only inhabitants of the Lynn Canal area in southeastern Alaska were a few traders, trappers, and Indians. With the influx of goldseekers during 1897-98, Skagway came into existence at the place of their debarkation and start on the 500-mile long trek to the Klondike. The town became much more important after the Whitehorse Pass route came into common use, and it likewise profited from construction of the rail line of which it was the seaboard terminus. By 1898, its population was estimated variously at from 15,000 to 30,000. With exhaustion of the gold fields upon which its temporary prosperity was based and discovery of gold in the beach gravels at Nome in 1898, a second stampede occurred and Skagway lost population rapidly. By 1900, there were only 3117 inhabitants; by 1910, but 872; at present, less than 500.

Petroleum and Settlement. Though the present intensive search for petroleum is of recent origin, it is prosecuted vigorously, since this mineral is one of the most important commodities known to civilized man. Advent of its use spelled the doom of whale oil as an illuminant; general employment of the internal combustion engine in automobiles, airplanes, on our farms, by rail lines, and in many industrial plants, assured its present importance. Search for it has, as a result, carried man from the margins of the polar ice sheets into the heart of the steaming tropics.

If discovery of oil occurs in an area with prior successful settlement based on agriculture or some other economic activity, as in California, the new-found wealth adds to local prosperity. Even if the pools occur under cities, a forest of derricks rises, as in the Los Angeles area. In the heart of Oklahoma City, Oklahoma, they dominate the state capitol itself. To avoid destruction of buildings under such conditions, the walls are drilled at a slant, so that recovery of the oil does not disturb either the buildings or the normal activities they accommodate.

By contrast, if discovery occurs in a region of limited opportunity and sparse population, as in many of the poorer agricultural areas of the southwest, in Texas and Oklahoma, change is great during the period of drilling and flow of the wells. Movements to many such oil fields are fully equal to the most frenzied of gold rushes. Converging roads are cluttered with trucks loaded with pipe and oil rigs; burdened with building material to erect permanent structures to replace the tent cities which spring up almost overnight after each new discovery; and choked with people moving in to take advantage of fancied opportunity.

During the early history of such boom towns, prices are fantastically high. At such times, coffee has been reported to have sold at 50 cents a cup, and cot space in a henhouse to have rented for $130 per month. In these communities, almost everyone is hopeful of a lucky strike which will make him wealthy, though such expectations are seldom realized. After a time, settlement as-

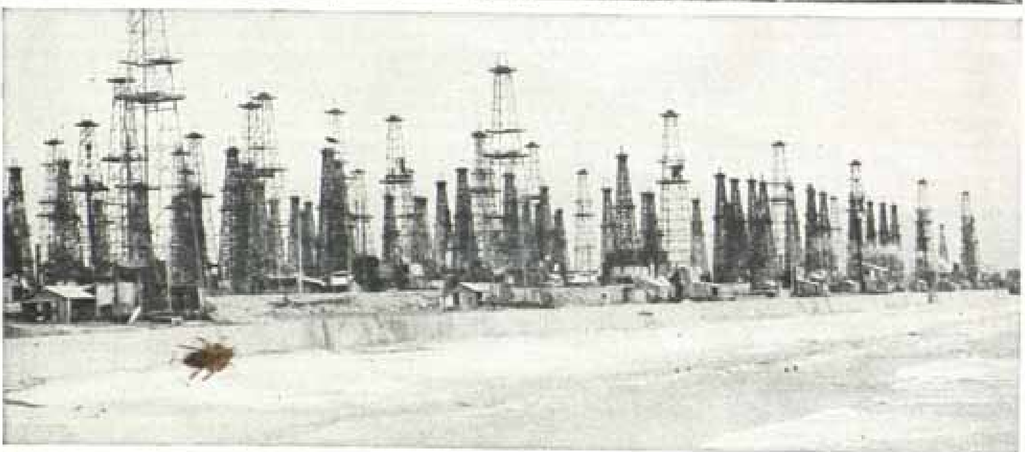


FIG. 333. *Top:* A maze of oil derricks, Signal Hill, about 2½ miles northeast of Long Beach, southern California. Gas compressor plant in the right foreground.

Middle: Drilling for oil at the ocean's edge, Huntington Beach, near Los Angeles, California. Such a large number of wells represents both excessive, unjustified expenditures for production and wasteful exploitation. (Courtesy of the U. S. Bureau of Mines.)

Bottom: At Summerland, near Santa Barbara, California. Not only do wells line the shore, but drilling operations have been extended to the ocean bottom.

sumes some stability, a condition it maintains only while the wells yield their "black gold." Thereafter, decay is generally rapid, for often no basis for permanent support remains. Then the oil men and their rigs move on to other sites where the same succession of events will occur. Thus the progress of drilling in the United States is marked by relics of boom exploitation in many localities.

In the Cumberland Plateau, for example, discovery of oil in areas where subsistence agriculture was the basis for support caused displacement of the farmers, who sold their land for relatively small amounts. Then the drillers came in, put down wells, and the area hummed with activity for a few years while the wells were productive. When their flow stopped and pumping became unprofitable, the oil men abandoned the area, but the farmers did not return. The mineral wealth produced neither remained in the area nor benefited it appreciably. Today, these areas are even poorer than before invasion by the drillers, and often practically without inhabitants.

Coal-mining Communities. Coal-mining communities are much more stable than those whose economy is based on petroleum, for the life of the mineral resource which affords the basis for their existence is commonly much longer and therefore the inevitable collapse with termination of mining operations is longer deferred. Some, indeed, may persist for many years, with wise management, for the amount of coal available may be enormous and the rate of its removal slow. There are several areas in the United States where mining of coal affords the principal basis for support. From one of these, located in the Cumberland Plateau of eastern Kentucky, two communities, one supported by several small workings, the other by a single large mine, will be described briefly to illustrate what such settlements are like.

Hazard, a Coal-mining Community. Hazard is located on the North Fork of the Kentucky River, in the heart of the Kentucky Mountains, in this locality a maze of ridges and valleys trending in many different directions, with only limited amounts of flat land along the stream courses, and ridge tops so narrow that they support no population. Roads therefore follow the creeks and, where the valleys are narrow, they may even occupy their beds. Earlier, the population was supported by hunting, fishing, and limited agriculture; later, by agriculture and lumbering. But with rail construction, coal mining has become important and supplanted agriculture as the major economic activity in those valleys focusing on Hazard, Perry County, where rail lines permit economic exploitation of the reserves of high-grade coal. Supported by this new activity in the tributary valleys, Hazard has grown from a collection of a few houses to a flour-

FIG. 334. Tipple or storage and loading equipment of a small mine near the mouth of Messer Branch, near Hazard, Perry County, eastern Kentucky. To the right and in the distance are some of the miners' houses, arranged in linear fashion on the limited flat land bordering the creek.

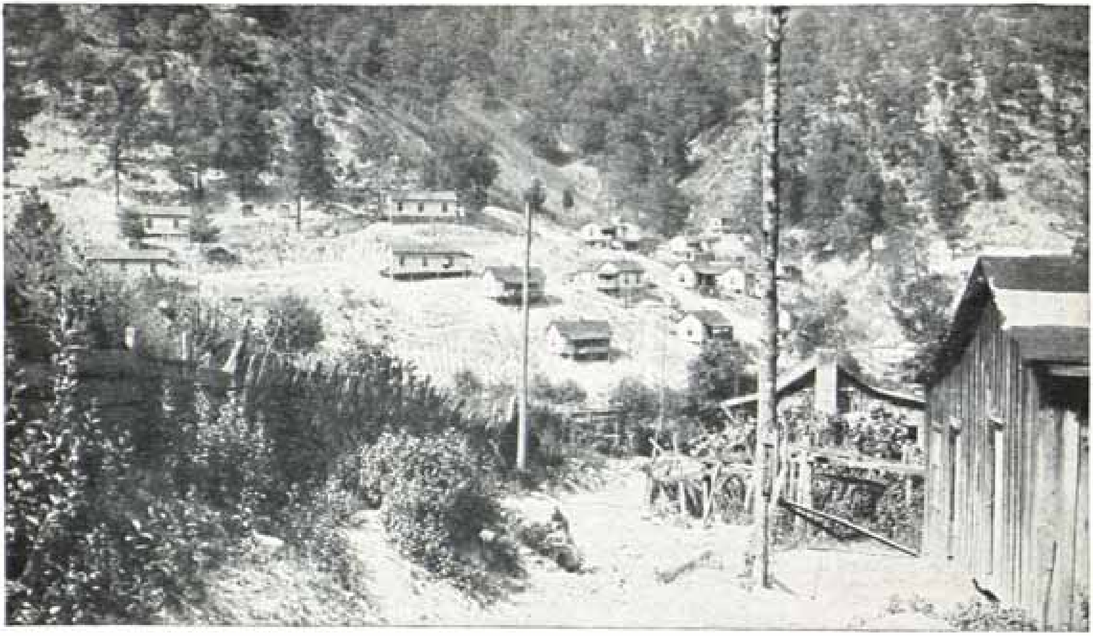


FIG. 335. *Top:* General view of a mining camp on Messer Branch, with the houses located on the lower slopes of the valley.

Bottom: Messer Branch mining camp in August, with hogs feeding on household refuse thrown in the street. These scavengers provide the only means for disposing of such wastes.

ishing population center with more than 6000 inhabitants, as contrasted with less than 600 in 1910, before coal mining became important.

One of these valleys is that of Messer Branch, a small north-flowing tributary of the North Fork of the Kentucky River. Its penetration for a short

distance by a spur of the main rail line has permitted mining to displace the older, less profitable agricultural and other use of the land in the lower valley, though beyond the point to which the rail spur penetrates, earlier uses of the land still persist. The mines are all small; some are no more than farmer diggings. Occupancy and the associated living conditions, here as elsewhere in the coal-mining area tributary to Hazard, reflect that fact.

The developments are simple drifts into the hillsides, for the beds of coal, exposed on the slopes by the erosional processes which formed the valleys, are horizontal. Mining is therefore simple, the coal sliding by gravity from the mine mouth far up the hillside to the tipple, later to be loaded into cars. Then it moves down grade by rail to markets west of the mountains.

The miners' houses are confined to the valley floor and the bordering lower slopes, therefore settlement is linear in character. In distant view, these mining camps may appear neither unattractive nor depressing but, on closer inspection, the impression gained is different. Where the small developments are numerous and the mines are close together, the crowding which ensues often leads to very unsatisfactory living conditions. On the flat land along the branch, it eliminates the possibility of gardens and intensifies the problems of sanitation. Where the houses spread over the hillside, as shown in Fig. 335, they may be without adequate approaches, for construction of streets, except on the flat land near the branch, is difficult and expensive.

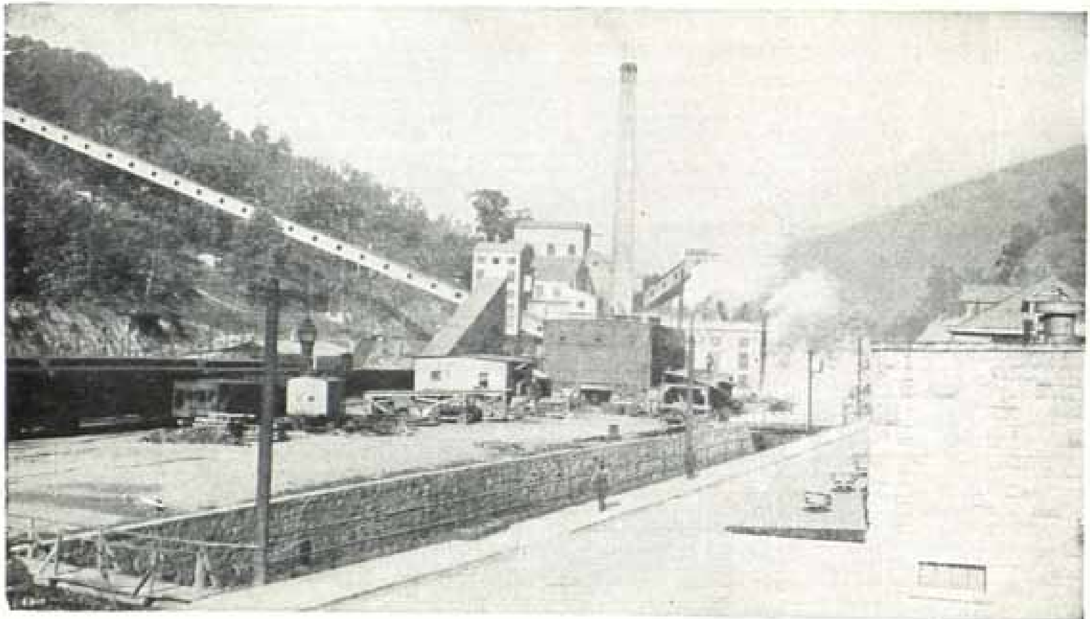
Houses parallel the railroad tracks, which follow the creek. Thus to the clatter and dust of the coal in the tipple are added the noise and smoke of the trains. Tin cans, garbage, and refuse of all kinds are dumped in the street and many of the houses are without toilets of any sort; others have filthy vault privies. There are no sidewalks; after a heavy rain one must step cautiously from stone to stone, over pools of filth. The stream, which flows intermittently, is an open sewer. Therefore on a hot summer day the stench is almost intolerable. Pigs, cows, and chickens roam the streets and both pigs and chickens have the run of the houses as well. A typical street of this character is shown in Fig. 335.

The houses, owned by the mining companies, are generally rectangular, one-story, two or four-room frame structures set on posts, with small porches across the front. They are usually unplastered and often unpainted, but generally wired for electric lights. Rents are normally about \$2.00 per month per room, which includes fuel and light, the heat being supplied by a fireplace, supplemented by a coal-burning range.

Few of the houses are screened and no sanitary precautions are observed in many of the camps. Flies, which breed in the garbage and other filth, constitute an ever-present menace during hot weather and the frequently contaminated water supply adds to the danger of disease, since wells are seldom protected from pollution and the same is true for the springs which furnish most of the water for domestic use. The preceding picture of average living conditions in the smaller camps is in no way overdrawn, but to improve them will be difficult, for the operators of the smaller mines can hardly incur the expense necessary. Further, the fault does not lie entirely with the mining companies for, when attempts are made to improve sanitary conditions, passive if not active opposition is often encountered from the miners and their families.

Lynch, a Large-scale Coal-mining Camp. Lynch is a linear mining camp in Harlan County, eastern Kentucky, located on the narrow bottoms of Looney Creek, between two spurs of Big Black Mountain. Earlier, this valley was occupied by a few poor farms, similar to those characteristic throughout those portions of the Kentucky Mountains not invaded by rail lines. Today, coal mining has replaced agriculture completely in the vicinity of Lynch, so that where formerly only a few scattered farmhouses were located, there is now a flourishing community of at least 2000 inhabitants. By contrast with Hazard, however, Lynch is supported by one large mine operated by the United States Steel Corporation. Here, large-scale development conserves the resource as well as decreases the costs of mining, a great contrast to the inefficient and wasteful operations of most of the small-scale mines of the Hazard area, many of which can be worked at a profit only when coal is high in price. Other similarly large mines at Jenkins and Benham, operated by the Consolidated Coal Company and the International Harvester Company respectively, support communities similar to that at Lynch.

Lynch is an attractive coal-mining camp. The hotel, churches, hospital, commissary, post office, and other major buildings are substantial struc-



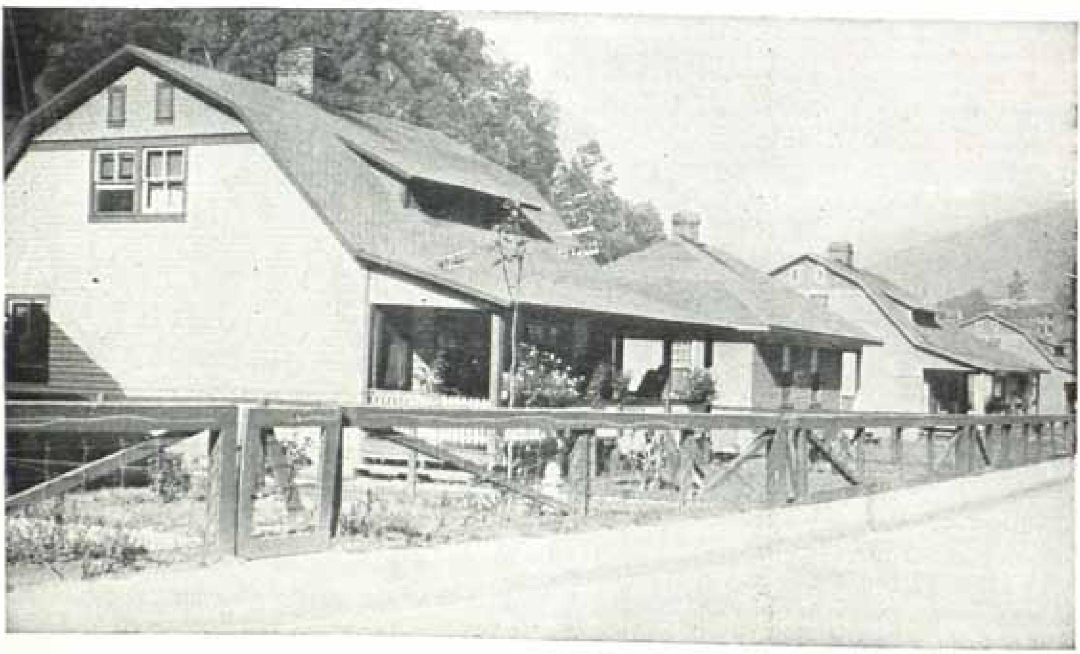


FIG. 336. *Top:* The million dollar tipple at Lynch, Harlan County, Kentucky. *Bottom:* Some of the miners' homes at Lynch, Kentucky.

tures, many of brick or stone construction. Houses, though small, are neat and in good repair, painted, electrically lighted, connected with a sewer system, and provided with running water and sanitary toilets. Yards are of fair size and architecture is sufficiently varied to avoid undue monotony. Streets are paved and well lighted and grades are moderate. Green lawns and flowers are

common and add to the pleasing appearance of the community. Conditions in all the larger camps are much like those at Lynch, and most of them are provided with recreation grounds and ball parks.

Garbage is removed and the attempt is made, rather successfully, to keep pigs out of the street and livestock of all kinds out of the houses. This is accomplished by company ownership and policing of the premises. The water for all these larger camps is piped from deep wells, large springs, or some other satisfactory source of supply. At Stearns, in McCreary County, condensed steam is used. In all cases, it is safe to drink. School buildings in the larger camps are good; the school year is of fair length; and instruction is much above the average for eastern Kentucky. This is in part because the teachers can secure satisfactory accommodations in company hotels and clubhouses, so that it is possible to attract competent instructors.

It will have been noted that there are marked contrasts in living conditions in coal-mining camps. They are at their worst where numerous small mines crowd one another, so that sanitary conditions become unsatisfactory; they are at their best in the larger, more efficiently operated camps, where effective extraction of coal is the common practice. To improve conditions in the smaller camps will be difficult and perhaps impossible because of the chronic financial embarrassment of all the small companies, and lack of cooperation by the workers. In all, however, defacement by mining, accumulation of mine wastes, and pollution of surface waters is inevitable. Therefore, over any extended period of time, all coal-mining communities become at least relatively unattractive in appearance.

Hibbing, an Iron-mining Community of the Mesabi Iron Range, Minnesota. The world's most important occurrences of iron ores are those of the Lake Superior region, among which the deposits of the Mesabi range in northern Minnesota are the most extensive, valuable, and productive. Hibbing, a mining community in western St. Louis county, is located in the heart of this range, which extends for more than 100 miles in a general east-west direction across Cass and St. Louis counties. Its story is that of a hole in the ground: the Hull-Rust mine and the associated workings, for from this yawning cut has come the wealth which made Hibbing and affords its present support. But as the mine pit grows in size and the ore flows steadily down the slope to Duluth, the future of this community appears far from promising, despite its present prosperity.

The valuable ore bodies in the ferruginous or iron-bearing, sedimentary formations of the Mesabi were formed by weathering and removal of silica and other somewhat soluble compounds by leaching, which produced local residual concentrations of the less soluble iron oxides: the soft and porous ores of very high iron content characteristic of the most easily worked deposits. Because there has been little if any disturbance of the strata subsequent to formation of the ore bodies, they are near the surface. This makes them particularly valuable by simplifying their mining, in many places possible by open-pit operations where the amount of overburden is small. This great advantage is supplemented by the possibility of gravity haul to Duluth, where very effective handling equipment and cheap water transportation to the smelters await them. It is this unusual combination of easily mined, high-grade ores, and other favorable conditions, including specialized cargo carriers and cheap water transportation to market, which has led to the extensive development of mining operations which support the towns of the Mesabi Range, including Hibbing.

Though the occurrence of iron ore near Gunflint Lake in northeastern Minnesota was reported as early as 1850, and the deposits of the Vermilion and Mesabi ranges were known by 1866, it is not remarkable that these deposits did not assume importance until later, for exploration, discovery, and development were difficult in this rough, barren, rock-strewn wilderness, where the tortured roots of ancient mountains form the surface and many swamps and dense growths of timber impose additional obstacles. With completion of the first rail line to the Mesabi in 1892, ore began to be shipped and, by early in 1895, it began to move from the Hibbing district. These ores were so different from anything found earlier that there was some doubt as to their value and at first the smelters objected to them. Further, the quantities were so enormous it was feared placing them on the market would depress prices to a point where all profit would disappear.

The first mines were developed by individuals with little capital, and the ore bodies were cut up into many small holdings. The ensuing cut-

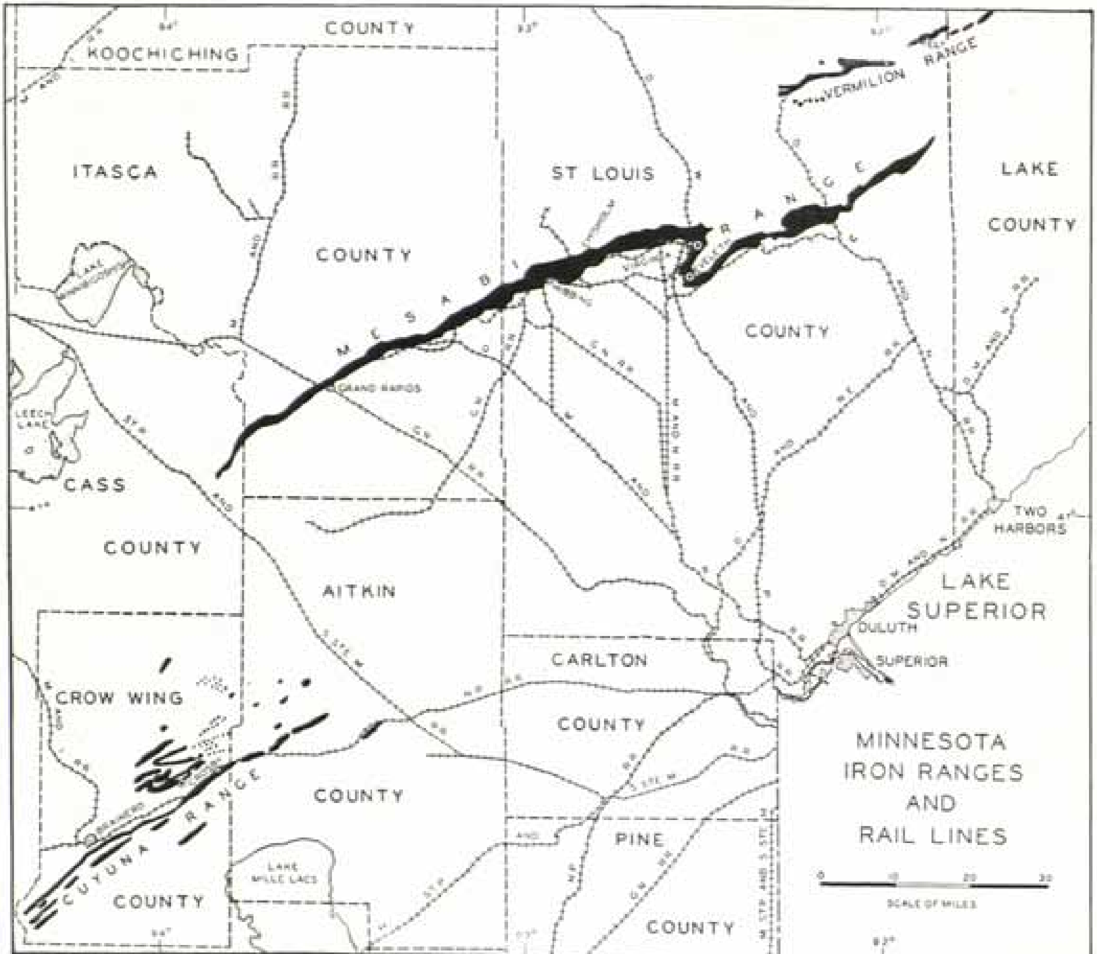


FIG. 337. Map to show the location of the Iron Ranges of Minnesota, some of the mining towns and their rail lines.

throat competition forced selective mining, or utilization of only the highest grade ores and enormous waste of those of lower iron content. By 1900, it was apparent that the only hope of prosperity for the operators and the community was extensive consolidation. This was accomplished in 1901, at which time the United States Steel Company took over the mines through one of its subsidiaries. Since that date, there has been an orderly and systematic development of the deposits and mining has been carried on economically and with a view to maximum recovery and utilization of all commercial ore.

The first producing mines were underground workings, but open-pit operations began shortly thereafter for, by early 1895, development of the present Hull-Rust-Mahoning property, the world's largest open-pit iron mine, was started. The first stripping was by hand shovels and wagons, but these were soon displaced by small steam shovels and horse-drawn dump cars, shortly to be replaced in their turn by larger steam shovels and trains hauled by locomotives. But even this equipment was soon out of date and much larger shovels, some capable of handling 6 to 9 cubic yards at a time, were installed. By late in 1917, this improved equipment made possible the mining and shipment of 1400 loaded ore cars each day during the height of the season.

Steadily mounting wages for labor have been offset by an ever-increasing and more effective mechanization of mining operations. Shovels no

FIG. 338. A portion of the Hull-Rust-Mahoning Mine, the largest open-pit iron mine in the world, Hibbing, Minnesota. The 350-ton shovel, purchased in 1923 and originally operated by steam, but now electrically powered, has a bucket which will handle 16 tons of iron ore. (Courtesy of the Hibbing Tourist and Information Bureau.)

longer move on fixed tracks, but are mounted on caterpillars. This gives them greater flexibility in use. Further, most of them are now electrically operated, for with iron miners and other workers demanding and receiving higher wages, use of steam shovels became too expensive. There has likewise been a steady increase in the size of the units of the mechanical equipment. Most of the dippers on the new shovels, for example, will handle 5 cubic yards, or as much as 16 tons, of iron ore; trains of ore cars operating in the mines are made up of 15 or more cars, with a total capacity of at least 750 tons of ore, and these are hauled by locomotives weighing 127 tons. The most recent development has been the installation of Diesel-powered tractors. But for this extensive use of machinery in mining, production would be smaller and steel would be higher in price. Thus the change in practices has been beneficial to the consumer.

Hibbing, the iron capital of the world, grew up around the Hull-Rust-Mahoning mine from which a total of more than 100,000,000 tons of ore have been taken, and from the entire pit, nearly 275,000,000 tons. This pit is 2½ miles long, ½ to 1 mile in width, and somewhat more than 350 feet in maximum depth. It covers 100 acres and contains a total of 70 miles of railroad track. On this huge development depends the prosperity of Hibbing, within the corporate limits of which it is located.

The original town of Hibbing was a typical northern Minnesota pioneer settlement, characterized by unattractive buildings, mostly of frame construction. When mining operations expanded to the extent that the pit surrounded the north part of the village on three sides, the mining company purchased the 40 acres threatened and moved many of the buildings 1¼ miles south to the townsite of Alice, a thriving suburb of Hibbing. This transfer, started in 1918, was completed by 1921. The earlier growth of Hibbing was rapid. By 1900, the 1895 population of 1085 had increased to 2481; by 1910, to 8832, and by

FIG. 339. Map of the world's largest open-pit iron mine and its relation to Hibbing.

1920, to 15,089. Since then, growth has not been spectacular, for there have been no new developments and increasing mechanization of the operations has held down employment, even when the output of ore has soared. Therefore the 1930 population was but 15,666, and that of 1940, only 16,385. Hereafter, no considerable increase may be expected, but rather a decrease, with exhaustion of the iron ore.

During the pioneer stage of its development, the population of Hibbing, like that of other young mining towns, was predominantly male, and the percentage of its inhabitants in the middle-age groups was disproportionately high. During this same period as well, when the mines were operated by local owners with small capital, and their success was uncertain, the amount of taxable wealth was small, and thrift, conservatism, and efficient management of public funds, imposed by necessity, were the rule.

With the success of mining assured, the pioneer stage of development disappeared, settlement assumed an appearance of stability, and population became more normal in composition. Then the mines were purchased by the United States Steel Company, a great corporation. When this occurred, community thrift disappeared. Enormous sums were spent for public works and paternalism characterized the administration of public affairs; all at the expense of the "soulless corporation." The question for many years has not been the necessity for any given public service or improvement, but the maximum tax possible to impose on the company, for that alone placed a limitation on expenditures. The voters have thought of the iron-ore resource as something to be dissipated to purchase temporary personal benefit. Most of them could not and many still cannot conceive of any mutual advantages accruing to both the corporation and themselves from a proper division of profits, if any, and development of the mineral wealth without waste, with a view to prolonging the years of existence of Hibbing.

This condition has persisted for many years, but a belated awakening to realities is now beginning, though unfortunately not always in the mining communities themselves. There, the view still all too commonly held is that the iron ore is a purely local resource, to be administered with as little profit as possible allowed the mining companies; the maximum of individual benefit for the residents of the local communities, not the state; and without any great amount of thought given to the future.

This situation is disturbing. Since 1915, shipments of high-grade ores have exceeded discoveries and since 1920 screening and beneficiation of ores have been common. In 1942, concentrates comprised 23.9 per cent of all ore shipments. This indicates that the life of the better ores is limited. In fact, 50 per cent of all the high-grade ores had been exhausted by the 50 years of mining before the outbreak of the war. During the past few years, with war needs paramount, the drain on the remaining tonnage has been so unprecedently great that today not to exceed one-third of the original reserve remains. Even before the war, the life of the resource was estimated to be not to exceed 20 to 30 years; today, it is much less, with probably not more than 10 to 12 years of high-tonnage production. This

FIG. 340. Howard Street, Hibbing, Minnesota. At the left is a modern 160-room hotel; across the street and in the distance, the business blocks are substantial, attractive structures and stores are well stocked. (Courtesy of the Hibbing Tourist and Information Bureau.)

FIG. 341. Hibbing High School and Junior College. This structure, with an attached garage and athletic field, covers four city blocks; the main building alone, 416 feet across its front, covers 7 acres. With a 60-foot wide, theatrically equipped stage, and an auditorium which seats 1822 persons, this school accommodates 2200 students and offers instruction ranging from the kindergarten through the first two years of college work. Completely equipped with swimming pools, gymnasia, and all else money can buy, it is the show educational plant of this part of the world. (Courtesy of the Hibbing Tourist and Information Bureau.)

raises the question as to the future of Hibbing when all the ore has been mined. This is a nonagricultural region; the commercial timber has virtually all been cut; the last of the iron ore is being mined. What will happen when the mines pull out?

The only possibility of any considerable extension of the life of iron mining in the Mesabi Range is utilization of the enormous reserves of taconite, low-grade deposits containing 20 to 35 per cent iron. The steel companies are interested in this possibility, it is true, but they are likewise investigating the ore resources of other countries, particularly those of Labrador and Brazil, where billions of tons of high-grade ores which can be mined cheaply are available. For this reason, the future of iron mining in Minnesota, and that of Hibbing as well, will depend in considerable part on tax policies.

Some Recent Developments in the Mining Industries. In addition to such spectacular developments as the great access of importance to certain deposits of uranium ores used in manufacture of the atomic bomb, there have been others, especially in the U.S.S.R., and particularly to the east of the Urals, which have not attracted the popular attention they deserve.

Even though available estimates may not be entirely reliable, it is now virtually assured that the U.S.S.R. ranks second only to the United States in mineral wealth. This is almost certainly true as regards coal, 90 per cent of which is in Siberia. There, in the Kunetz Field alone, and this is only one of five important producing areas, the bituminous reserves are more than 450,000,000,000 tons, equaling those of our Appalachian Field, and annual production exceeds 20,000,000 tons even now. Siberia likewise has large amounts of iron ore, some manganese and copper, much lead and zinc, and valuable gold occurrences. Further, though much prospecting still remains to be done, the known mineral resources are sufficient to make their present and potential impact on world affairs of great importance.

Mining and the Conservation of Mineral Wealth. In consideration of the fact that mineral

FIG. 342. Mechanized loading equipment of a U.S.S.R. coal mine in the Ukraine. This extensive use of mechanized equipment is typical of recent mining operations in the Soviet Union. (Courtesy of Sovfoto.)

wealth is an irreplaceable national heritage, because the processes which operate to produce commercial concentrations of minerals work much too slowly to offset the drains resulting from man's demands on the deposits stored during past geological time, it is desirable that conservative practices should be followed in their mining and use so that the date when substitutes must serve may be deferred as long as possible. Such conservative practices in extraction and utilization became more necessary each year, for the volume in which minerals are used mounts yearly with discovery of new uses for all, and uses for some not formerly considered of value, accompanying our steadily rising standards of living.

The various recommendations to accomplish these ends, made at different times and by many individuals, fall into two groups, as follows: (1) suggestions for economical recovery in mining operations; and (2) plans to assure efficient distribution and use of minerals.

By "economical recovery" is meant mining at minimum expense, so that cost of the product to the consumer may be held at the lowest possible figure compatible with essentially complete recovery of commercial deposits. Such recovery is advantageous in conserving the resource because it eliminates the necessity for selective mining, or use of only the highest grade deposits to operate at a profit. At present, much mining, particularly in the small-scale operations, is extremely expensive and possible only under favoring conditions of deposit and market. It is probable that such operations should be eliminated completely.

In mining, it is desirable to remove as much of the mineral wealth as possible at the time of the initial exploitation of the deposit. Otherwise, future recovery of what remains will always be difficult and may even be impossible. In a coal mine, for example, the coal not recovered during the first working of the deposit probably cannot be removed at some subsequent date, for the mine may fill with water and shattering of the seams and crushing of the coal are common when a shaft is abandoned and the strata settle. Even if the old workings can be reopened and the remainder of the coal mined, the costs of operation are increased greatly. After the coal has been brought to the surface, it is also important that it be handled without undue waste, though this is not always done. For example, in substituting wet-jigging for hand picking because it was cheaper and yielded temporarily higher returns, the Pennsylvania anthracite industry has thrown away 500,000 tons of coal annually and, as a by-product, plugged the lower 150 miles of the Schuylkill River with coal dust during the past 50 years. This is not only a waste of coal but detrimental in other respects as well.

Efficient distribution and use of minerals are also fundamental in any wise utilization of our mineral heritage. For example, shipping coal ordinarily involves burning coal as fuel or, if not, at least use of some other source of power which could be employed to better advantage than for moving coal an unnecessary distance to market. Efficiency in the use of minerals is obviously economical of the resource and of assistance in prolonging the life of these irreplaceable deposits to the maximum.

If we plan wisely and use our mineral resources intelligently, there is no reason for undue apprehension concerning their future exhaustion. Otherwise, the outlook for the future is not promising, for our present civilization is based on the use of minerals; without them, it would be impossible, for we have no satisfactory substitutes. To entrust development and use of a natural heritage such as mineral wealth entirely to unregulated individual initiative is probably unwise, in view of the well-known proclivity of each individual to think in terms of his own immediate self-interest. This is not confined to those who exploit the minerals, but extends to those who exploit the producers as well, evidenced by the situation which exists in many mining communities. In the public interest, therefore, the regulation of mining and use of minerals should be entrusted to those whose interests are sufficiently removed to make them approach the problem as objectively and realistically as possible. Certainly it is true that mineral wealth should be administered as a public trust, not as the private possession either of some individual or of a given interested local community, for this lesson is one which all should be able to read from the experience of the past.

To ensure prosperity in peacetime and security in times of national emergencies, therefore, measures should be taken to protect the public interest. These would not involve nationalization of mining, but only regulation of operations as carried on by private enterprise.

QUESTIONS AND EXERCISES

1. Under what conditions will commercial concentrations of mineral wealth occur? From what two types of parent material are such deposits derived? Illustrate by examples.
2. In what fundamental respects do mineral deposits differ from most other natural resources? How would their exhaustion affect man?
3. How have both the actual and relative importance of mining varied with time? Why? How does the culture of a population group affect the importance of mining? Illustrate by examples.
4. How has the search for minerals added to our knowledge of the earth's surface? Illustrate by examples.
5. Compare the relative importance of mining in Illinois and Nevada. Why the difference?
6. Describe the effects of physical conditions of the strata and the location of mineral deposits on the values of different types of mineral deposits.
7. How does discovery of petroleum affect areas of different types? Has such discovery always benefited areas permanently? Illustrate by examples.
8. Contrast the different types of coal-mining communities in the Cumberland Plateau of Kentucky. Why do conditions vary so greatly from place to place? What does this indicate as to desirable mining operations?
9. What fortunate combination of conditions makes the iron-ore deposits of the Lake Superior district so important?
10. Describe mining operations in the Mesabi Range and the changes which have occurred since the mines began production.
11. Describe the rise of Hibbing, the "Iron Capital" of the world.
12. What is the attitude of the Hibbing community with reference to the mines, and in what respects is this unfortunate?
13. What does the future hold for Hibbing with exhaustion of the high-grade ores? How long before this exhaustion will occur?
14. What is "taconite"? Under what conditions will its use be possible to prolong the life of the iron-mining industry in the Lake Superior region?
15. What recent developments in the mining industry promise to have marked effects on world affairs?
16. In what ways have we used our mineral resources unwisely up to the present? Illustrate by examples.
17. Why is it especially desirable to use our mineral resources wisely and what steps should be taken to ensure such use?
18. Why should formulation of a policy of use of mineral resources not be left to individual initiative?

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Chapter Thirty-Six

FISHING AND SEA HUNTING

The Waters as a Source of Food and Other Products. The animal life of the waters, both fresh and salt, affords an obvious source of food and other products of value to man. Therefore fishing and sea hunting have long been economic activities of variable importance in all latitudes, wherever rivers, lakes, or bodies of salt water have afforded an opportunity for such pursuits. Today, for example, the Fang and many other less advanced populations of the tropics depend on fishing to supply some of their food, and the Eskimo of the Arctic and other primitive inhabitants of the higher latitudes of both the Northern and Southern hemispheres turn to the sea for part or even most of their support. This was equally true for primitive peoples of prehistoric times, for whom we have no records except such as have been deciphered from the midden or piles of refuse about man's former camps. These activities of backward populations of the present do not normally contribute to commerce but serve only to afford partial or complete support for relatively small numbers; only among groups which have made considerable advance do either fishing or sea hunting assume important commercial significance.

It is, of course, not necessary to turn to areas of limited opportunity in low and high latitudes to find examples of primitive fishing populations, for many of the Indian tribes of the Pacific Coast of North America, from Oregon north to Alaska, have long been fisheaters, dependent largely on salmon for food. Thus Lewis and Clark reported native fishing in the Columbia and its tributaries in 1805-06, and use of fish, fresh, cured, and in the form of pemmican, or dried, pulverized, and packed in sacks, as the principal food of an estimated 50,000 Chinook and other Indians in the area they visited. Today, farther to the north, some such groups have even embarked on commercial fishing for support, as at Metlakatala, a model Indian village near Prince Rupert, Canada, where a modern cannery permits preparation of the catch for market. Some of the villages of these fishing populations, located on streams up which salmon runs occur, have attracted much attention because of their remarkable totem poles: 25 to 50-foot high, elaborately carved armorial monuments of their owners. One such 50-foot pole, removed from its original site, now adorns Pioneer Square in downtown Seattle, a fitting monument to the importance of salmon in the Puget Sound country. A typical Indian fishing village of this type is that of Kitwanga, on the north bank of the Skeena River, 150 miles inland from the Pacific. There the salmon, revered properly as the major source of support, is abundant in this Indian Garden of Eden, that "Good Land of the Old," where the "sun laughs in joy" at the abundance of nature.

Location and Extent of Commercial Ocean Fisheries. The extent of the oceans is great, but that of their important fishing grounds is much more restricted, for areas where commercial catches of valuable food fish may be secured are limited to a relatively few localities with exceptionally favorable natural conditions. Thus, except for specialized types of fishing, such as for coral, shell, pearls, and sponges, important commercial fisheries are lacking in the tropics, for though the warm oceans teem with life, including many bright-colored fish, the valuable food fishes of commerce live only in the colder waters of intermediate and higher latitudes. Again, commercial fishing is possible only where food supply for the fish is abundant. Thus zones of contact of warm and cold currents, which occur in combination with other favoring conditions only in

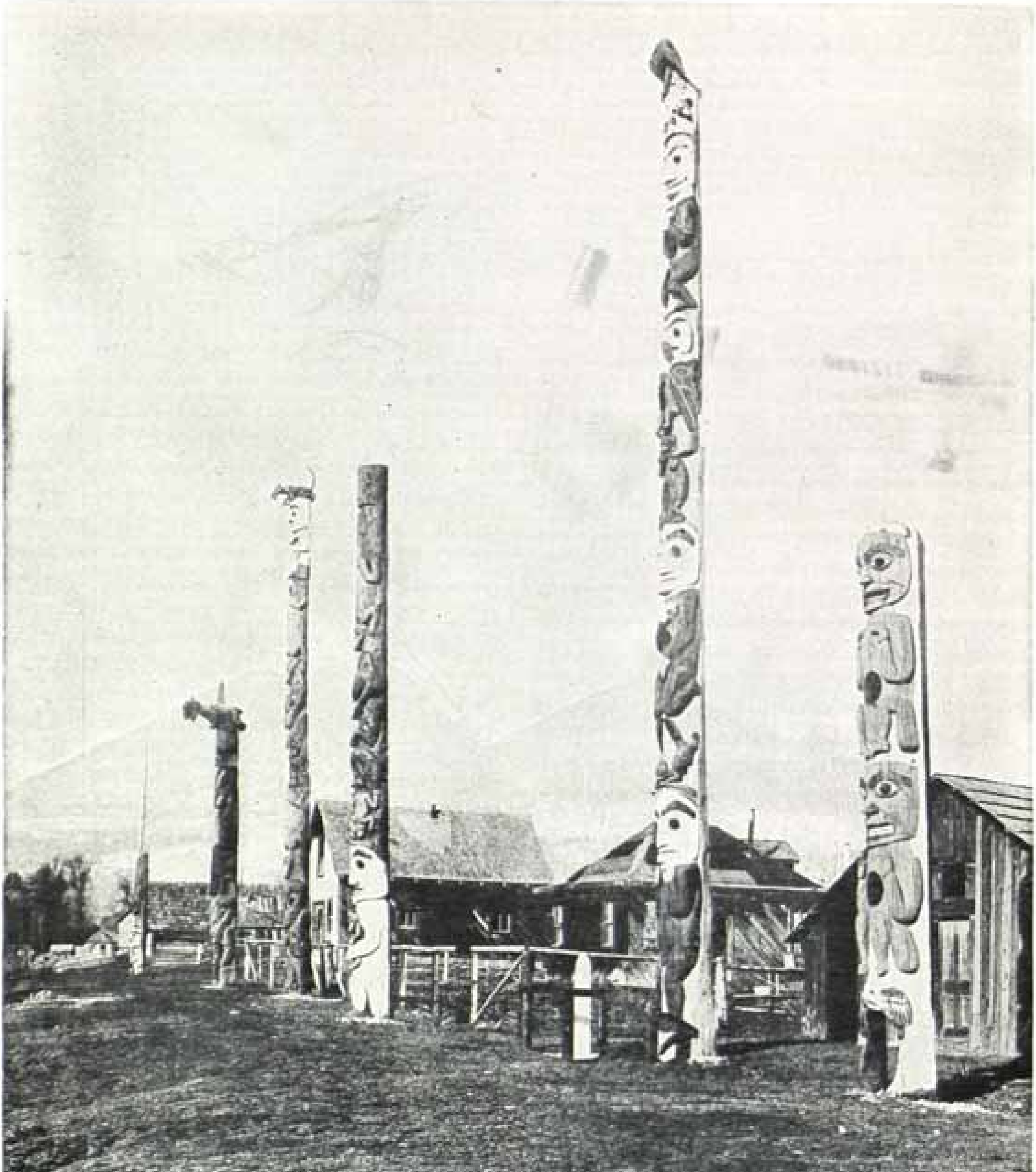


FIG. 343. Kitwanga totem poles, brightly painted and elaborately carved with the "crests" of the owners and the animals or "totems" believed to be the ancestors or guardians of the families, together with symbolic references to incidents of the family history. Thus one at Kitwanga, among other facts, commemorates the tradition that a former chief, dragged from his canoe and carried to the "salmon town" by a giant dog salmon he had speared, became so familiar with the habits of the salmon that, after his return to Kitwanga, he was able to catch them at will. (Courtesy of the Canadian National Railways.)

the Northern Hemisphere, are localities where commercial fisheries with a catch of considerable value for human food have developed. In addition, the important food fish are confined to shallow coastal waters or to those portions of the ocean where shallows or banks occur. Therefore the great fishing grounds of the world are in such localities, wherever ocean temperatures are likewise favorable. This is mostly in middle latitudes or on the margins of the polar seas. These are the great fishing grounds of the North Atlantic and the North Pacific, where practically all the food fish which enter into world trade are taken.

The value of the catch of the fisheries of the world is small by comparison with the returns from many of man's economic activities on the land, the average annual total of about $700,000,000 being less than that of a single important crop such as corn or cotton. Further, though the industry is widespread, both its actual and relative importance are limited, except in a few localities. These in general tend to be those parts of the world where the land offers so little opportunity that, though fishing involves a life of hardship and danger, with uncertain and often unsatisfactory returns, it presents the most effective means of obtaining a livelihood available. Nevertheless, the great fishing grounds are important, for they not only serve to support considerable populations but they also furnish valuable training schools for mariners, which is of benefit to the world as a whole.

The world's important fisheries are of three general types: (1) inshore, (2) pelagic, and (3) demersal. The inshore fisheries, with which may be included those of the lower stretches of the larger rivers, operate in shallow coastal and fresh waters with small boats. Included in their catch, in addition to fish proper, are various crustaceans such as crabs and lobsters, and shellfish such as oysters. Pelagic fishing is prosecuted far from land and larger boats are employed, but the catch is confined to fish which live near the surface, with herring and mackerel making up most of the haul. Demersal fisheries, confined to shallow waters over banks and shoals, depend upon such fish as cod, halibut, haddock, hake, sole, and other bottom feeders. Therefore the equipment used is different in character from that employed to catch fish which live closer to the surface.

Fisheries of the Tropics. Fish form an important item of the diet in many tropical countries. Among some native populations, the demand is met by local fisheries, but where agriculture is the dominant economic activity, import may be necessary. In places, however, as in Java, there is likewise considerable fish culture in shallow, brackish, semiartificial ponds along the coast; in artificial ponds inland; and as a second crop on the flooded paddies. The same is also true in parts of South China.

In addition to catches of food fish, relatively unimportant in the lower latitudes except as they supplement the food supply of less advanced native populations of these warmer parts of the earth, the seas of the tropics support important coral, shell, and pearl fisheries, and, in limited areas, sponging. Off Florida, for example, sponges grow on the bottom where the water is shallow over reefs. These marine products are harvested by both diving and hooking, in waters which range up to depths of as much as 60 feet, though most of the operations are carried on in waters from 6 to 15 feet deep. Where the water is shallow, the sponges are gathered largely by hooking; where deeper, generally by diving. The Key West fisheries use the sponge hook exclusively. After the sponges have been collected, they are cleaned by maceration and washing, which removes the organic material, for the sponge of commerce is merely the "skeleton" in which the animal lives. Fishing for pearls, another industry of tropical seas, is a very ancient activity, prosecuted as early as the times of the Ptolemies in the Red Sea, though now unimportant there. In ancient times, pearls were likewise obtained from both the Persian Gulf and the seas bordering India, where fisheries still exist. In the Persian Gulf, these are today most important near the island of Bahrein; in India, off Ceylon, with a secondary center near Karachi. In the important Ceylon fisheries, operated under governmental supervision, the pearls are obtained by divers who work a few weeks each spring. Pearl fisheries are likewise of some importance in many waters off southeastern Asia, in the Sulu Archipelago, and off many of the South Sea islands. Pearls are also obtained from Australian waters, on both the east and west coasts. There are likewise fisheries in the Western Hemisphere, in the Gulf of California, and in limited areas to its south. Except off eastern Australia, the pearl oysters are harvested by divers; there they are obtained by dredging.

FIG. 344. Important fishing grounds of the world.

Sea Hunting in Polar Seas. The important "catch" in the seas of polar areas is not of fish but largely of mammals which live in the water and feed on sea life, some on forms almost microscopic in size, others on larger living organisms. The animals taken include whales, fur seals, hair seals, and walrus. Therefore the activity is sea hunting rather than fishing.

Before petroleum came into common use, or before the days of the kerosene lamp and the even more important internal combustion engine, whale oil was employed for many purposes, including illumination and lubrication. During this period, which lasted until late in the nineteenth century, whaling was an important industry in the Arctic. Even toward its close, though whale oil was in less demand, the uses for whalebone or baleen, today largely replaced by substitutes or not in use for the earlier purposes, still persisted, and, selling as it did at certain times as high as $10,000 a ton, trips of the whalers were often very lucrative. Occasionally, too, a lucky find of ambergris, used in the manufacture of perfume, either afloat or in a diseased whale, made a single voyage so profitable as to assure wealth to the fortunate vessel owner and a competence to the crew. Today, the whaling industry is unimportant in the Arctic, partly because whales have become virtually extinct in its waters. However, it still flourishes in the Antarctic. There, use of larger vessels, plus new methods of killing and handling of the blubber and meat in floating factories, a continuing though limited demand for the products, and the fact that a few whales still remain, have caused the industry to survive. Even in the Antarctic, however, the industry becomes less profitable each year, and, since the peak production of 1937-38, there has been a steady decline in the value of the catch. Unless regulated soon, the whaling industry of the Antarctic will go the way of that of the Arctic and the industry will dwindle to insignificant proportions or even disappear completely.

One of the more interesting of the sea-hunting activities of the higher latitudes is the sealing industry, particularly the taking of fur seals. Other aspects of less importance are the hunting of walrus, valuable for ivory and hides; and of the hair seal, a source of oil and skins. By contrast, the fur seal is valuable for its pelt, used in the manufacture of fur garments and trim.

Hunting of fur seals is centered in the Pribilof Islands in the Bering Sea, off the coast of Alaska. Earlier, they were taken everywhere in both the Arctic and Antarctic, and at all seasons. As a result, they are now virtually extinct south of the equator and few are known in the Arctic, except for the herd of the Pribilof Islands. This was likewise threatened with extinction by reckless and indiscriminate killing of both males and females, but pelagic sealing is now prohibited by international agreement, only males are taken,

and killing is supervised. In this herd, now numbering in excess of 2,000,000 animals, the ratio of males to females is 1:10, which experience has demonstrated as desirable. The present regulated killing of surplus males, which now yields about 60,000 pelts each year, has made possible a gradual building up of the size of the herd, a steady and increasing supply of pelts, and perpetuation of the industry on a stable basis. This illustrates the advantages which accrue from an intelligent conservation policy, applied to the fur seal; one of similar character for other forms of sea life which yields products of value to man would be equally advantageous.

The World's Great Fishing Grounds. The great fishing grounds of the world where the catch is of fish, all in higher middle latitudes, are four in number: (1) the seas bordering northwestern Europe and Iceland; (2) off the northern islands of Japan and in adjacent Asiatic waters ;(3) the shallows or banks off Newfoundland, Maritime Canada, and New England; and (4) the Pacific coast border of North America, from San Francisco to Alaska inclusive.

The Fisheries of Northwestern Europe and Iceland. The fishing industry of northwestern Europe is carried on in shallow waters over the continental shelf and the banks and shoals of the adjacent seas. Of these shallows, the most important is the Dogger Bank, an oval-shaped, submerged plateau in the North Sea with an area of 6850 square miles, covered by less than 120 feet of water.

Fishing is of three types: inshore, pelagic, and demersal, with shellfish an important part of the yield of the inshore operations. In the pelagic fisheries, herring make up most of the catch. The most important of the demersal fisheries are those of the North Sea and off Iceland, with cod, haddock, sole, plaice, halibut, hake, and other bottom feeders being taken, each from a definite location. The fishing boats, formerly propelled by sail, are today mostly power driven and some range up to 150 or even 170 feet in length. In the demersal fisheries, both trawls, wide-mouthed, tapering bags of netting, pulled along the bed of the sea; and seines, which differ from trawls chiefly in that the net rather than the vessel moves, are used. These fisheries extend from the Strait of Gibraltar to northern Norway and Iceland, where fishing is an old industry and fish the principal export. The fishermen in-

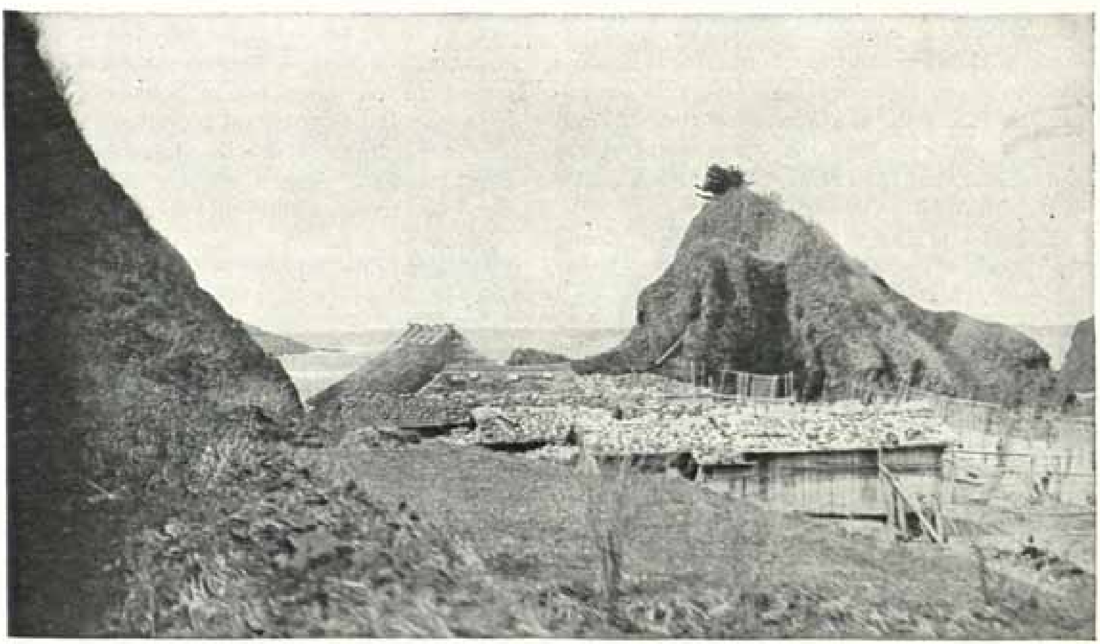


FIG. 345. A small fishing village on the west coast of Honshu, Japan. Here, there is no agriculture and, wedged in between the sea and cliffs, the houses of the fishermen occupy all the flat land, except for a small area used for drying nets.

clude Scandinavians, British, French, Germans, Dutch, and Icelanders. In all, they number approximately 200,000 and their annual catch is about 4,000,000,000 pounds, northwestern Europe leading the world in export of fish. However, the industry is not equally important everywhere for, in northwestern Europe as elsewhere, fishing is relatively more important where opportunity is least on the land. Therefore fishing becomes both actually and relatively more important in the poorer areas than where the land affords varied gainful employment.

Fisheries of Eastern Asia. Fishing is an important occupation in this densely populated part of the world, wherever opportunity presents, for the land alone is unable to supply all the food needed by the enormous population, approximately 25 per cent of the world's total. Along the Inland Sea of Japan, for example, except as interrupted by headlands, fishing villages form an almost unbroken line of settlement. The same is almost equally true for many stretches of the west coast of Honshu. In southeast China as well, where but little flat land is available for agricultural use and population averages 2680 persons per square mile of cultivated land, fishing is a common pursuit, either as a part-time occupation or a full-time activity. The fisheries of eastern Asia, however, assume their maximum importance in Hokkaido and Karafuto. This is because the conditions there are very favorable for important food fish, the shores of these islands being washed by both the warm water of the Kuroshio or the Japan Stream and the cold water of the Owashio or Okhotsk Current.

Fisheries of Japan. Japan ranks first among the nations of the world in the importance of her fisheries. This is in considerable part because of natural conditions: 924,000 square miles of fishing grounds, six times the area of Japan, and both warm and cold currents. Further, Japan is very attenuated. In few places is the main island, Honshu, as much as 150 miles in width; in its narrowest part, only 77 miles. In all, the four main islands alone have 9390 miles of seacoast: 1 mile for each 16 square miles of area. Including the smaller islands, this increases to 1 mile of coast for each 9 square miles of area. Living as they do in such intimate contact with the sea, it is not remarkable that the Japanese have turned to fishing to secure part of their food supply. Further, opportunity is limited on the crowded land and religious beliefs as well as economic necessity often prevent eating meat. Therefore fish and fish products form important items of the national diet as well as finding other uses, including food for animals and fertilizer for the naturally poor soils which are cultivated so continuously and intensively.

The fisheries of the warmer waters off the coast of Japan supply bonito, tuna, sardines, crustaceans, oysters, and other shellfish; those of the colder waters, herring, salmon, cod, sea trout, and other valuable species of fish. The activity is of both the subsistence and commercial types, with commercial fisheries more highly developed in the north. In all, nearly 1,500,000 persons are employed, either part or full time, by river, inshore, and open-ocean fishing and the manufacture of fish products, with nearly two-thirds of that number by the fisheries proper. A total of 360,000 boats is used, mostly small and without engines, though the use of motors as well as the size of the fishing boats is increasing rapidly. The larger boats normally operate not only in Japanese waters but also in those of Siberia, by agreement with the U.S.S.R., and they have even attempted to invade the coastal waters of Alaska. After the First World War, there was a considerable development of floating crab canneries, the product being marketed in the United States, Australia, and Europe. One reason for the rapid increase in the importance of Japanese fisheries, aside from favoring natural conditions, has been their encouragement by the Japanese government, extending even to subsidy of vessels engaged in transportation of deep-sea catches. Further, as a means of encouraging seasonal movement to the fisheries of the north, the government-owned rail lines grant special round-trip rates to fishermen during the summer months. These are all statements of conditions prior to the war; what effect it will have on future operations is not clear at present, though it is probable that the change, if any, will not be great.

Fisheries of China. The sea has never played the important role in the economic life of China that it has in Japan. This is because the relatively short 3000-mile coast line of China is smooth, with few and mostly poor harbors. This is particularly true in North China. Again, most of the population lives far from the ocean. In southeastern China, where conditions are more favorable, fishing becomes of greater importance, for there

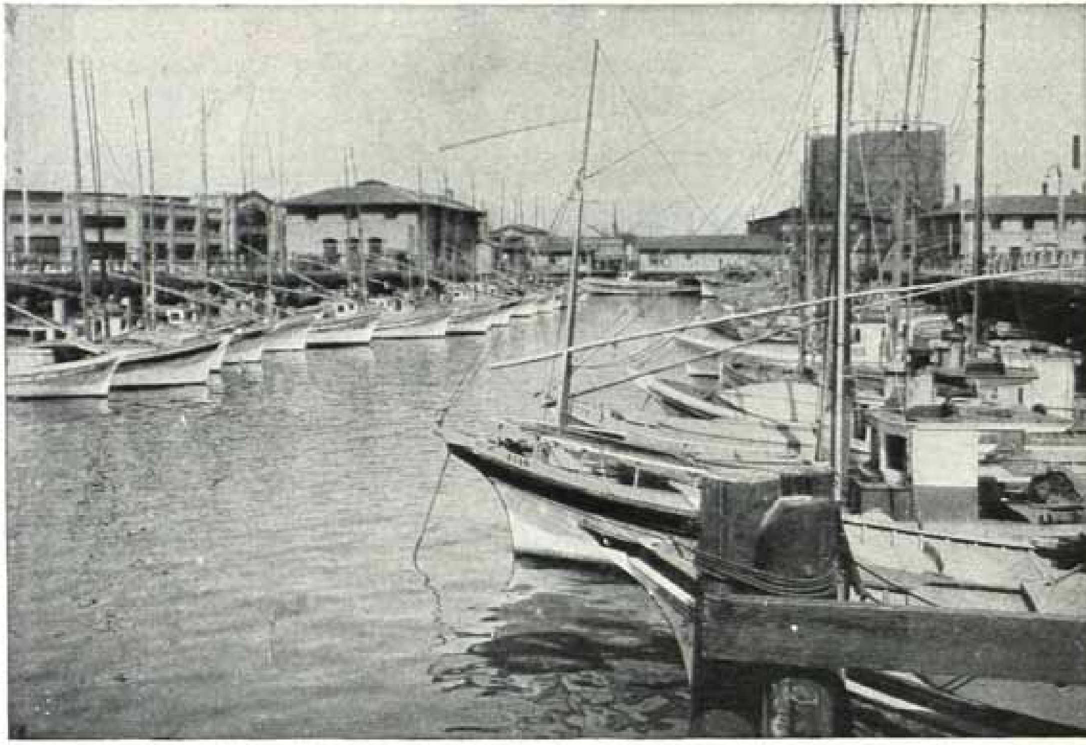


FIG. 346. View of the famed "fishermen's wharf," San Francisco, California. Though the fisheries of the southern part of the Pacific coast are of less importance than in the past, many small fishing vessels still operate in the San Francisco area, supplying local markets with fresh fish. The same is true in the Los Angeles region but, being farther south, the catch is of fish of the warmer waters. (Courtesy of the Redwood Empire Association.)

the land offers less opportunity and more numerous harbors and timber for building fishing boats are available. Fish, however, are those of the warmer waters, and the catch is much less important than in northern Japan. The Chinese not only engage in sea fishing but they utilize as well the opportunity afforded by numerous waterways and canals, thus supplementing to a considerable extent the supply of food secured from cultivated fields.

North Atlantic Fisheries of the United States and Canada. The fishing grounds off northeastern North America, which include the coastal waters of the North Atlantic seaboard and the shallows or banks of Newfoundland, have been of great importance for several hundred years. The Newfoundland fisheries, for example, were known to the Biscayans and Normans as early as 1504, and, before 1600 they were visited annually by as many as 500 fishing boats: English, French, Spanish, and Portuguese, in the order of their numbers. They were considered so valuable that, when the French relinquished Canada and most of their landholdings in the New World to the English, they reserved rights on the fishing grounds and kept possession of Great and Little Miquelon and St. Pierre, three small islands south of Newfoundland. Similarly, the United States retained fishing rights on the Banks after the Revolution, for at that time the fisheries of New England were of great relative importance.

These fishing grounds owe their importance to a combination of favoring conditions, for there the cold waters of the Labrador Current meet the warm waters of the Gulf Stream over extensive shallows. Of these banks, the largest and most important is the Grand Bank, southeast of Newfoundland, where 37,000 square miles of the ocean's bottom lie less than 360 feet below its surface. In addition, there are others of smaller

size, including Green Bank, St. Pierre Bank, and several in the Gulf of St. Lawrence and to the southwest of Newfoundland, with a combined area of several thousand square miles, so that the fishing grounds are extensive.

From these shallow waters are taken a variety of food fishes; herring and mackerel from near the surface; cod, halibut, hake, and others at greater depths. Alongshore, the waters supply shellfish and lobsters. Fishing is by hand lines, trawl lines, steam trawling, nets, and traps. These fisheries are the principal basis for support of the populations of Newfoundland and parts of the Maritime Provinces of Canada, and they also supply a source of income and support to considerable numbers in New England, where they afford employment to approximately 16 per cent of all commercial fishermen, and a catch valued at about 20 per cent of the total for the United States in an average year. It should be realized, however, that though of some actual importance in New England, fishing is today a relatively minor economic activity there, for it is overshadowed by others, particularly manufacturing. Fishing is likewise of some importance farther to the south along the Atlantic seaboard and in the Gulf of Mexico, but there the fish of the cooler waters of the north are replaced by mullet, shad, striped bass, bluefish, menhaden, and others, many not of any great value for food.

Pacific Coast Fisheries. Fishing has been an important industry on the Pacific Coast for nearly 100 years, for its beginnings are tied up with the early history of Oregon, Washington, and British Columbia, whose settlement was based, not only on the fur trade, but on fisheries as well. Thus a few cases of pickled salmon from the Pacific Coast were sold in Boston as early as 1830; by 1832, the Hudson Bay Company was marketing fish in Hawaii, Chile, and Great Britain. By 1846, commercial fishing was firmly established in both United States and Canadian waters. Though other fish, including cod, halibut, flounder, mackerel, and trout are taken, salmon are so much more important that the fishing industries of the West Coast are commonly thought of as salmon fisheries only. In all, these give employment to nearly 20 per cent of all the fishermen and account for almost 35 per cent of the total value of the catch for the United States in normal times.

Salmon are particularly easy to take for, though they spend most of their lives in the ocean, they spawn, or deposit their eggs, in rivers. When these hatch, the fry or young salmon remain in fresh water for a short time, thereafter migrating to the ocean, where they live for from 2 to 6 or 7 years. Then they return, generally to the same river where born, to spawn and die. In all, there are five species of salmon: the chinook or king, the sockeye, the humpback, the silver, and the dog or chum. Of these, the chinook is the most valuable, the sockeye and humpback important, and the chum the least desirable. These five species range from central California, to Alaska inclusive, but the relative importance of each varies in different localities.

Salmon are taken at the time of runs up the rivers, which occur from January to early October, both the time and number of runs varying with the river. Drift and gill nets, hand and purse seines, floating and stationary traps, trolling, and fish wheels are used in fishing during the runs, though the last method is now illegal. Salmon are also caught on lines at other times. If all the ascending fish are caught, that run is destroyed, for no fish are born to return later to spawn and die. Further, if the spawning grounds are not reached, even though no fish are caught, the result will be the same. In 1913, for example, closing of the Fraser River by a slide prevented an estimated 85 per cent of the fish from reaching the spawning grounds, thus destroying one of the greatest of Fraser River runs.

Salmon fishing had become important on the Pacific coast by the middle of the nineteenth century; in the Seattle area, as early as 1850. By 1882, the Sacramento River pack was 200,000 cases, though now there is none from that region, for the industry has shifted north, particularly to Alaskan waters, with the disappearance of profitable fishing in many areas farther to the south. By 1920, there was a marked decrease in the catch everywhere, even in Alaska.

This decrease was in part an inevitable consequence of overfishing; in part it was caused by pollution of streams, the breeding place of the salmon. To some extent, also, it resulted from lowering of river waters by their use for irrigation and diversion of fish into inadequately screened ditches. Agriculture, grazing, and lumbering operations also contributed, for they increase soil erosion, scouring of stream beds at times of freshets, and denudation of the stream banks.

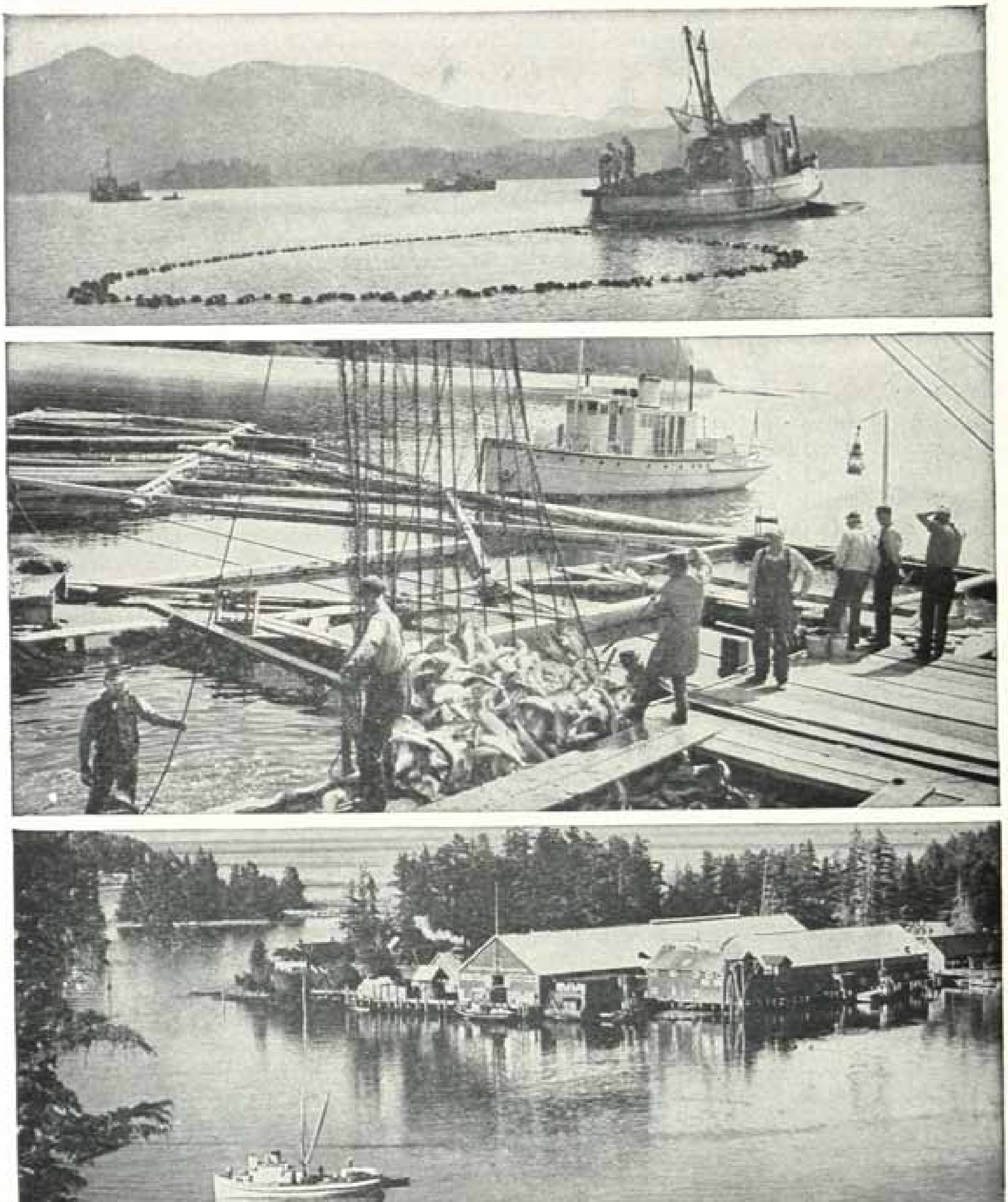


FIG. 347. *Top:* Taking salmon by use of a purse seine, southeastern Alaska.
Middle: Brailing salmon from a trap, Alaska.
Bottom: An Alaskan salmon cannery in sheltered waters. Built on piles, boats are able to tie up at the dock to discharge fish and easy disposal of cannery wastes is possible. (Courtesy of the U. S. Bureau of Fisheries.)

The last allows the sun to raise the temperature of the waters of the smaller tributaries and destroy the insect food of the fish. In addition, lumbering operations often block the streams with log jams. Man's construction of dams for various purposes has likewise produced unfavorable results. Some of the smaller dams, it is true, are equipped with fish ladders, but some, such as the Coulee Dam, are so high that runs cannot pass. To prevent this loss, the fish were trapped below the dam; eggs were removed from the female fish, fertilized, and transferred to hatcheries. Later, the fry were released in streams which discharge into the Columbia below the dam. Today, the mature fish are returning to these same streams to spawn, thus preventing in part at least the loss resulting from construction of the dam. This is important, for the fishing industry of the Columbia has an estimated capital value of $250,000,000 and an estimated annual return of $10,000,000. Despite all steps which may be taken, however, it is probable that the dams already built, plus others planned, will tend to decrease the size of the runs.

It is highly desirable to protect the salmon, which is one of the most valuable food fish of North America. With this in view, the Alaska fisheries were placed under the control of the Secretary of Commerce in 1924, since which date the Bureau of Fisheries has ruled that only 50 per cent of any one run may be taken. Fishing has likewise been regulated in the Fraser River across the International Boundary since 1937. It is to be hoped that these and other similar measures will ensure satisfactory and stable conditions for the salmon industry.

At present, the industry is centered in Alaska, which now supplies about half of the total annual pack, though the Puget Sound and Columbia River fisheries are likewise important. Though the bulk of the catch is marketed canned, salmon are also sold fresh, frozen, pickled or salted, and mild cured. In all, approximately 26,000,000 pounds of fresh salmon, valued at $1,000,000, are handled in Seattle alone, with frozen salmon of but slightly less importance.

Alaska is a particularly good location for canneries since there is an abundant supply of pure, fresh water and many safe landings for fishing boats along the highly indented coast. Modern canneries, most of which are built on piles at tidewater, represent investments of $200,000 or more, on which a return must be earned during a very short season of operation, sometimes of only 45 days. The present regulation of the Alaskan catch is highly beneficial for, in addition to other advantages, it tends to protect these investments. The bulk of the canned salmon is shipped to Seattle to be sold, with San Francisco and New York second and third in importance as markets. From these markets, it is exported to all parts of the world, with Great Britain, France, and Australia absorbing most of the product. Our principal competitor for export markets is Canada, with Siberia and Japan of lesser importance.

Lake Fisheries. Lake fisheries are generally of limited significance, except as they supply fresh fish for local markets. In the case of those of the Great Lakes, however, they are of considerable importance, with a yearly catch valued at nearly $6,500,000, and affording employment to more than 6000 fishermen. The industry is important in these lakes because of their size and the extent of the fishing grounds; the fact that the fish taken are of species important in commerce; and because of the nearness of the fisheries to large urban markets. For the most part, the fish are sold fresh, though some are smoked. In either case, most are used for human food, though some are fed to animals and used as fertilizer. As in fisheries elsewhere, the catch is decreasing, particularly that of the more valuable kinds such as whitefish, which have virtually disappeared from certain areas where formerly abundant. Therefore the present yield is largely of inferior species. This is unfortunate and emphasizes the desirability of restriction of fishing and regulation of the industry.

Hokkaido and Its Fisheries. Hokkaido, the northernmost of the four main islands of Japan, is a bleak and inhospitable region of but limited opportunity. Much of the land surface is mountainous, and, even in those areas where topography permits, climate does not greatly favor agriculture. In some parts of the island, indeed, the growing of cultivated crops is virtually impossible because of the prevailingly cloudy and foggy weather and the cool frost-free season. Everywhere, the few warm months and the length and severity of the winters tend to discourage settlement, particularly by Japanese, who prefer the warmer, sunnier regions of the south to the cold, cloud, and fog of Hokkaido. Despite

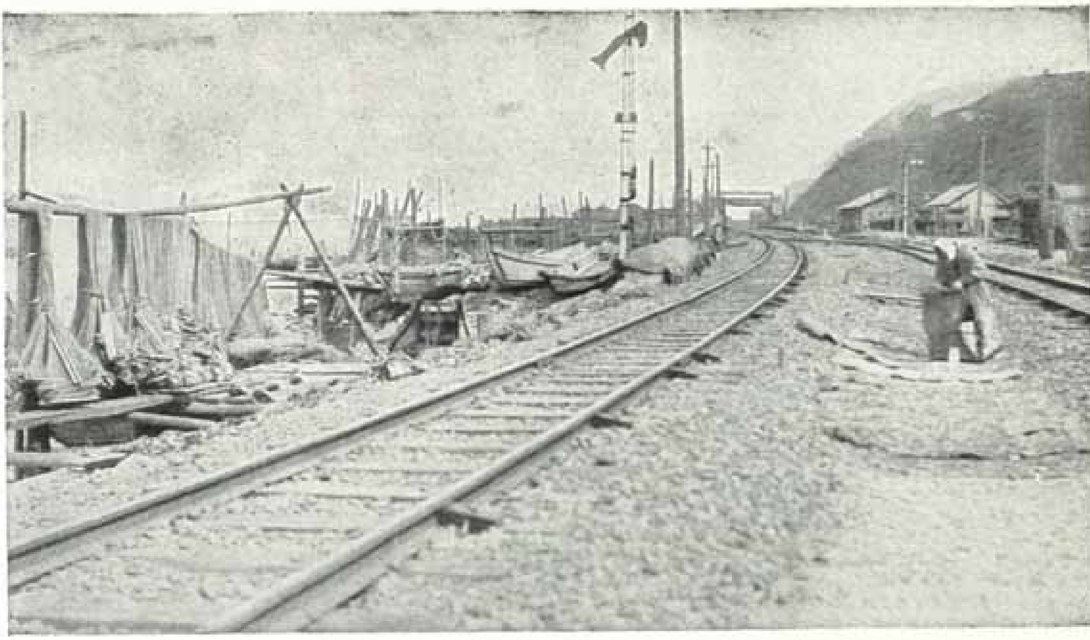


Fig. 348. *Top:* Asari, Hokkaido. The village is to the right of the railroad tracks, between which the ground is covered with fish products, spread out on matting to dry. At the left, drying nets, fishing boats, and racks for curing fish occupy all the land along the shore.

Bottom: Fishermen's houses, curing fish, and drying nets fill all the space to the right of the narrow, muddy, single street of the village. On the left, drying nets form a screen between the houses and the railroad tracks.

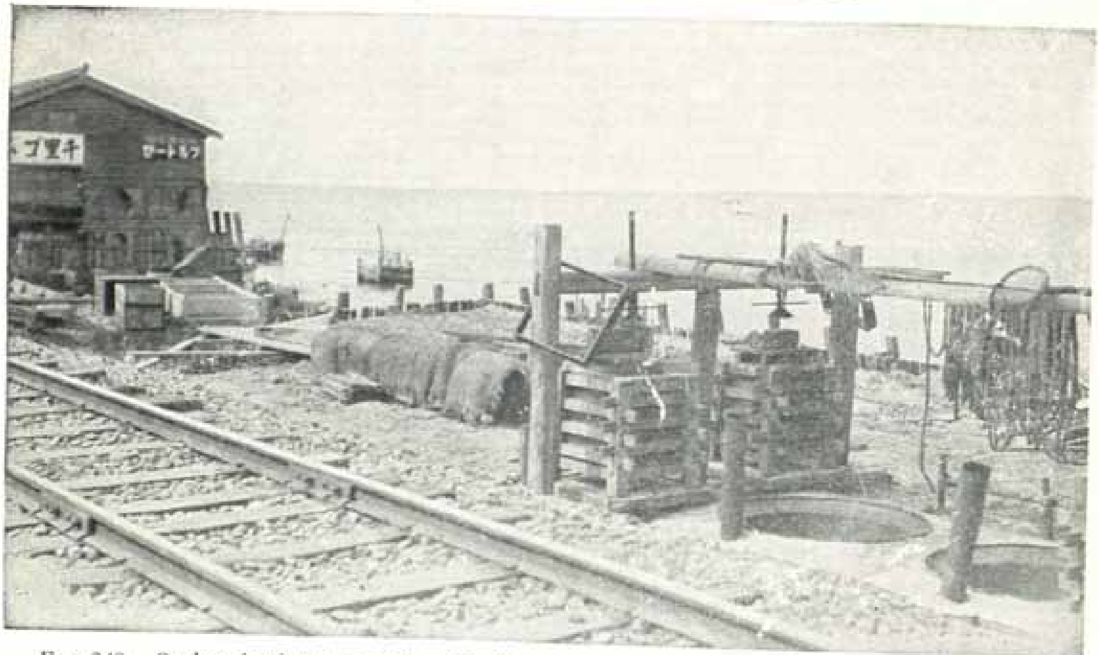


FIG. 349. Sunken kettles for cooking fish, fish presses, and curing and baled fish products occupy most of the space between the railroad tracks and the sea at Asari.

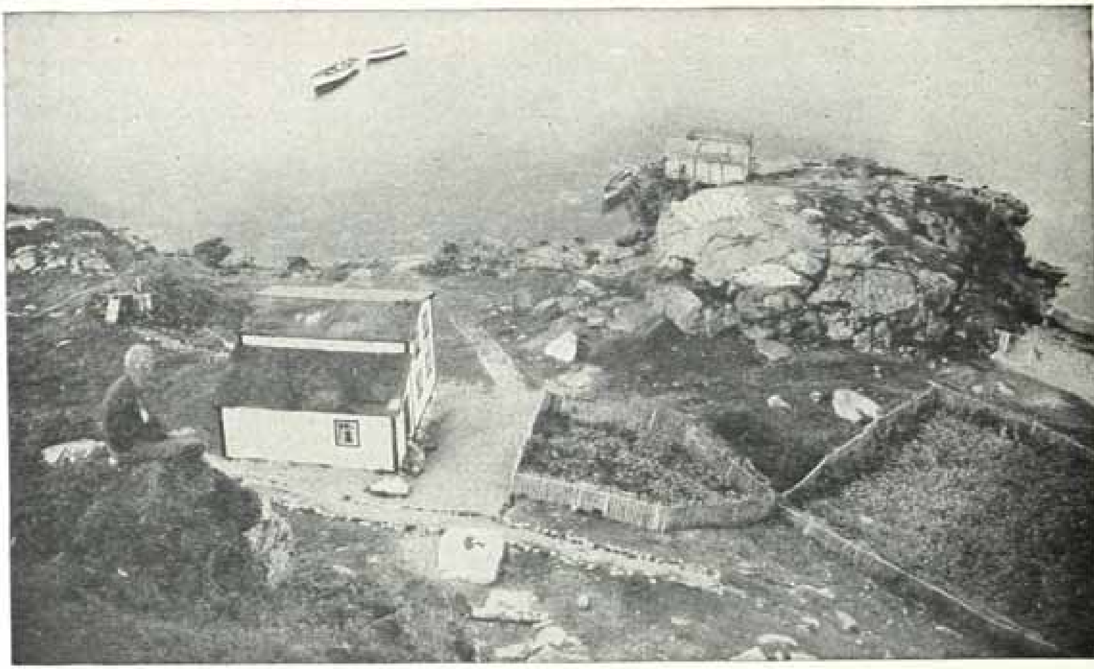
these handicaps on land, the bordering seas are rich in marine life, including valuable food fish, for Hokkaido is washed by both the Kuroshio and the Okhotsk Current, and offshore waters are shallow. Attracted by the possibility of fishing, there has been limited permanent settlement in the south of the island and seasonal migration to the Hokkaido fishing grounds for many years and, of late, fishing villages have sprung up on all its coasts.

Asari, located a short distance to the east of Otaru, an important city and port on the west coast of southwestern Hokkaido, is typical of these fishing villages. Like most of them, it is linear in form, for it is located on a narrow, flat-topped terrace bordering the sea, with the upland rising abruptly in its rear, an upland which, though occupied by scattered settlement, offers little in the way of attraction. In front of the village, however, is the sea, which presents opportunity for fishing, the sole support of the population of the community.

Not only is there little flat land at Asari, but part of this is occupied by the double tracks of the rail line which follows the shore at this point. Therefore the village is not only limited to a single street, but houses are confined to one of its sides, with the other lined by supports from which nets are hung to dry. The houses are set close together, virtually without yards, with such open space as exists between them occupied by frames filled with curing fish or draped with nets and other fishing gear. The street in front of the houses is unpaved, without walks, and barely wide enough for two vehicles to pass, for no level land is wasted, where so little is available. Between the tracks of the rail line and the sea, there is also a small amount of level land, which finds use for fish kettles, presses, and the curing of fish products; for drawing up the small fishing boats; and for drying and repairing nets.

Fish and the odor of fish are everywhere, for drying fish and fish products fill all the free spaces and, spread out on matting, also cover the ground between the railroad tracks and the openings along the waterfront. One would be conscious of the importance of fish in this community with his eyes closed, even on a cool day; when it is warm, the odor is almost overpowering. The returns from fishing are neither great nor certain, and Asari is far from a pleasant place in which to live. Here, at least, though the sea affords a living, its romance is lacking completely.

Most of the fishing is carried on close to shore



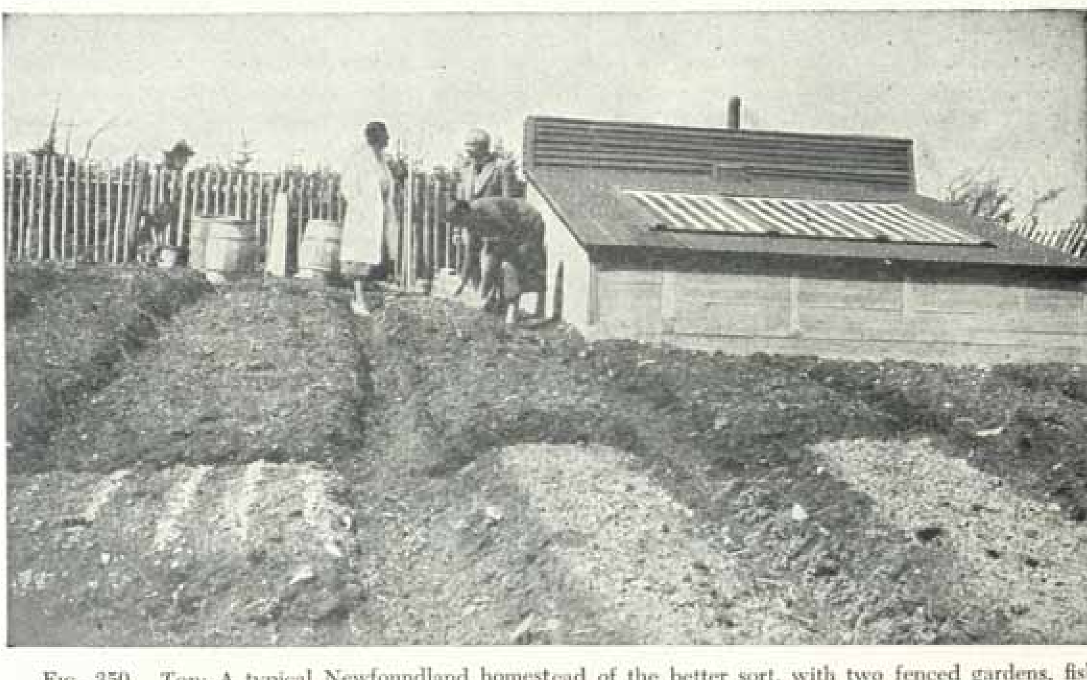


FIG. 350. *Top:* A typical Newfoundland homestead of the better sort, with two fenced gardens, fish drying on the rocks, a small wharf or stage, and a fish house.
Bottom: A typical fenced Newfoundland garden at Flowers Cove. The beds are built up to improve drainage and warm the soils. (Courtesy of Fred C. Sears.)

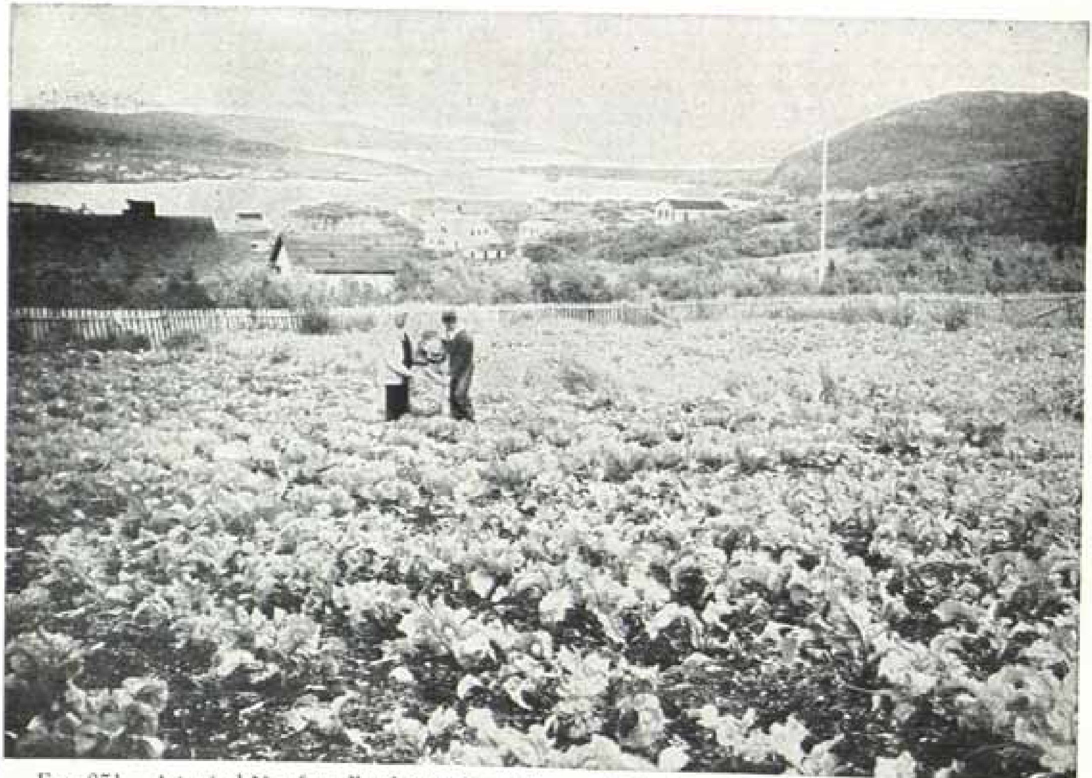


FIG. 351. A typical Newfoundland coast line and part of the fenced vegetable garden at St. Anthony. Cabbages are grown here, both to be sold as plants and to supply food for local consumption. (Courtesy of Fred C. Sears.)

with small boats, which can be drawn up on the land when not in use. When not engaged in fishing, the inhabitants of Asari, both men and women, put in their time caring for the catch and mending nets. Some of the fish caught, shipped in open or coal cars, are sold by the bushel to farmers of inland agricultural areas. There they are used for food, both by man and the domestic animals. For the latter use, they are cooked in large iron kettles on the farms and then fed to hogs and poultry. Some are also used as fertilizer, for night soil is limited in this northern island with its relatively sparse population. Some fish and fish products are also cooked in sunken kettles at Asari, then reduced in bulk by presses, and either sold locally or exported for use as fertilizer. There are hundreds of small fishing villages such as Asari along the coasts of Hokkaido, as well as in many parts of the southern islands, for population density in Japan is so great that many must turn to the sea for support.

Newfoundland and Its Fisheries. Newfoundland, like Hokkaido, is a chill, forbidding land with cool summers and much fog along its coasts. In addition, at least 75 per cent of its land surface of 42,000 square miles would be unsuitable for agricultural use even though the climate were more favorable. This is because Newfoundland has been heavily glaciated, so that the solid rock often forms the actual surface, and even where soils occur they are often excessively stony. This combination of thin soils and an unfavorable climate limits the possibility of agriculture to a few localities, possibly 8000 square miles in total areal extent, of which not more than half would yield crops, even of hay, oats, and potatoes; the remainder could at best support only a grazing industry of sorts. Agriculturally, indeed, Newfoundland is much less desirable than Hokkaido.

Like the northern island of Japan, much of Newfoundland is forested with coniferous timber: spruce, balsam, and fir. This forest is valuable for the manufacture of pulp and is now being exploited, but the industry furnishes employment

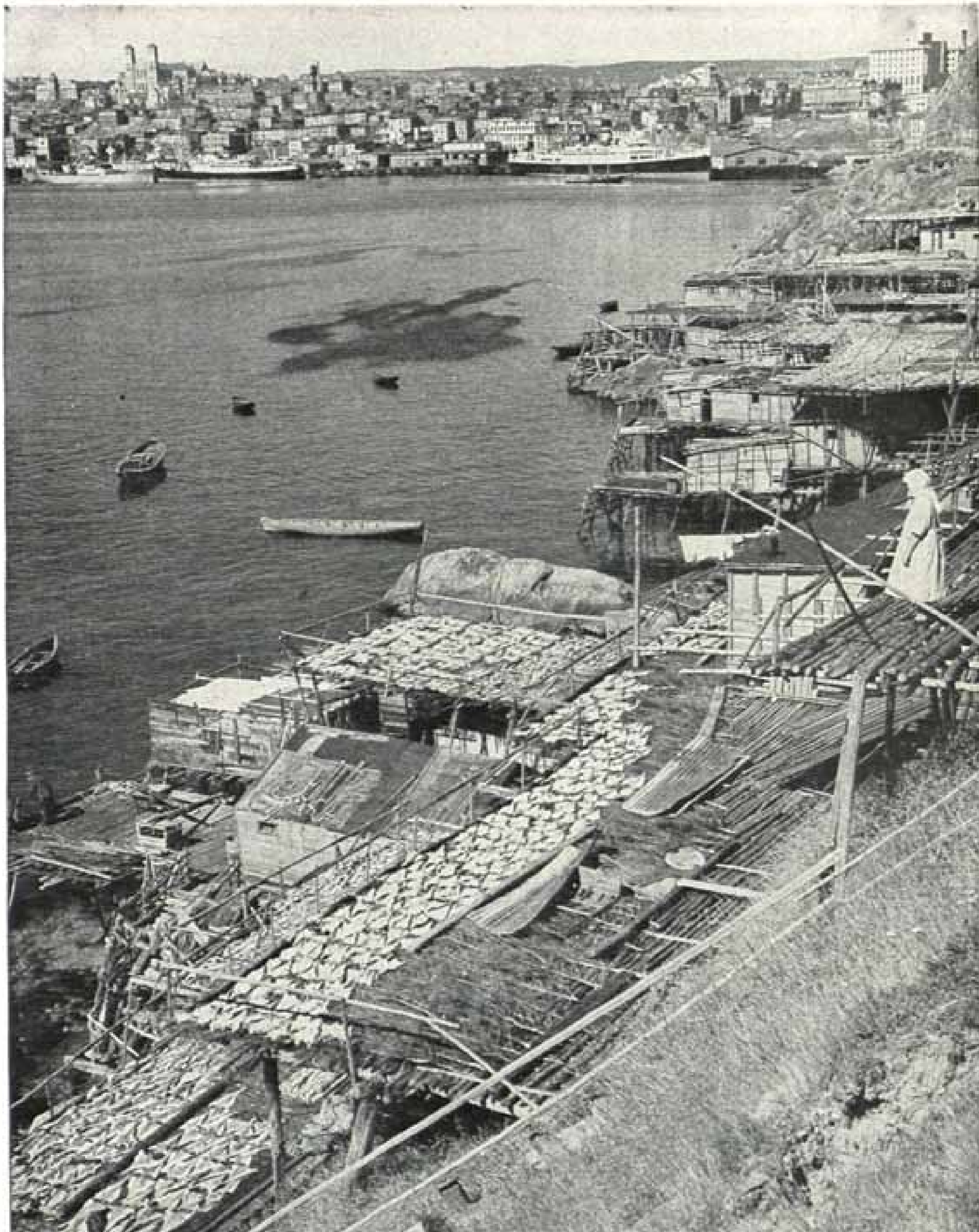


FIG. 352. A waterfront scene at St. Johns, the capital of Newfoundland. Here, as elsewhere, fish are much in evidence. In the foreground, they are drying on "flakes" of brushwood on the slopes along the shore. Below, along the waterfront, are the landing stages for the fishermen's boats and, in the distance, two passenger boats which normally ply between St. Johns and the ports of the mainland, and the British Isles. (Courtesy of Gustav Anderson.)

to relatively few workers and its life will be short. Newfoundland likewise has deposits of iron ore, but no coal; by contrast Hokkaido has coal but no valuable iron ores. Other mineral resources are of negligible importance in both islands, therefore mining affords employment to but few in either. Newfoundland, it will be noted, is even less favored by nature than is Hokkaido, for agricultural possibilities are more limited; the forest is less valuable; and mineral wealth is no greater, though different in kind. This lesser desirability possibly finds expression in differences between the populations of the two islands, for though Newfoundland is slightly more than 30 per cent larger than Hokkaido, its population is less than 10 per cent as great. In part, of course, this may reflect differences in race and standards of living of the inhabitants of the two islands, but it is undoubtedly in part because of lesser regional opportunity.

But though the land denies any considerable opportunity, the sea offers it, for Newfoundland's fishing grounds are equaled in few other parts of the world. Offshore, there are numerous shallows or banks over which the warm waters of the Gulf Stream meet the cold waters of the Labrador Current. Further, the fiorded or highly indented coast line offers many harbors to fishing boats. Therefore the inhabitants of Newfoundland depend on the sea for support to an even greater extent than do those of Hokkaido, it being estimated that, before the war, 66 per cent of all persons gainfully employed were fishermen. Despite the favoring natural conditions, however, the fisheries have not been prosperous of late years, and this has led to poor living conditions. Up to the outbreak of the war, in fact, they were almost desperate.

By that time, the $26,000,000 export of cod of 1918 had dropped to $5,000,000; the yearly income of the average fisherman was only $100; and 40 per cent of the entire population were dependent on the dole, either wholly or in part. During less than 20 years, the governmental indebtedness nearly tripled, so that it mounted to well over $100,000,000. These conditions resulted from smaller catches and lower prices for the fish sold, coupled with ignorance and poverty which prevented adoption of new methods of curing and packing, and compelled sale of the catch at low prices in order to move it. Wartime expenditures, it is true, have remedied this situation temporarily and the debt has been wiped out, but the future is far from promising.

The problems of Newfoundland are, of course, those common to all areas where unregulated, unsupervised fishing is carried on over extended periods of time, intensified by lack of other natural opportunity. We have them in the United States, but they do not attract so much attention because the areas affected are smaller and the number of their inhabitants is fewer.

The Future of Fisheries. Our increasing knowledge of the life history of fishes has led to growing concern over the disappearance of certain species and the smaller catches of others. Shortage of fish in the markets of the world may not be noticeable as yet, it is true, but this is partly because when one source of supply is exhausted, others are drawn on to an increasing extent. However, increase in the efficiency of fishing operations which makes this possible only brings nearer the eventual depletion of all sources of supply. Like our seemingly limitless forests of only a few years ago, now a thing of the past, the apparently inexhaustible supply of fish of the present is threatened today.

Examples to illustrate what the future has in store can be drawn from many sources. Earlier, for example, salmon were plentiful along the Atlantic coast from the Hudson River north to Labrador; today there is no commercial catch. Even on the Pacific coast, now the source of supply, the salmon is disappearing in many rivers where formerly abundant, and decrease in the catch is apparent almost everywhere, though the output of the canneries may remain essentially unchanged because of more intensive fishing and substitution of varieties different from those formerly taken. The disappearance of a given species is especially notable in the case of the shad, a fish of the South Atlantic seaboard which, like the salmon, spends its adult life in the sea but ascends the rivers to spawn. Unregulated fishing and pollution of the streams began to have noticeable effects as early as 1880; today the catch is only about 20 per cent of that of 1900, with resultant higher prices for shad and shad roe.

Up to a certain point only will increased fishing produce a larger catch; beyond that point, the yield will fall in spite of an increased expenditure of effort since, for every species of fish, there is an optimum rate of fishing. Taking due account of variations in annual catch which result from

natural fluctuations over which man has no control, it is desirable to restrict fishing operations to an extent that yields remain unimpaired. Not only should reckless exploitation of the fish of the coastal waters be prevented, but the fish and animal life of the deep sea also need protection. Whaling, for example, has practically exhausted the resources of the northern seas and of all waters except those of the Antarctic. Increased efficiency of operations makes ever greater inroads on the remaining fraction of the former resource of whales of these waters; certain species are already scarce, and all varieties are being killed faster than they can be replaced by natural reproduction. Further, there is no indication of any decrease in the demand for the production.

In some cases, regulation of fishing is possible of local solution, but in others, international agreements are necessary, for the fish which breed in certain waters may be caught far from the place of their birth. Again, certain types of fishing are carried on outside coastal waters over which any single nation has jurisdiction. Therefore effective control of such activities can be secured only by collective action. To take the steps necessary to protect valuable sea life is obviously desirable unless we are reconciled to eventual decrease in the profits of certain types of fishing and sea hunting, loss of a valuable source of supply of food and raw materials, and the disappearance of certain forms of marine and fresh-water life.

QUESTIONS AND EXERCISES

1. For how long a time has fishing been an important economic activity? Illustrate its importance to primitive populations by examples.
2. In what latitudes are commercial fisheries important? Where in these latitudes? Why? Of what types are the fisheries, and what are the differences between these types?
3. Describe the fisheries of the tropics as to their kinds and location.
4. What products does sea hunting yield? How has whaling shifted the location of its operations and why? Describe the sealing industry and the steps taken to protect it.
5. Discuss the fisheries of northwestern Europe and Iceland with reference to their location, favoring natural conditions, types, catch, and importance.
6. Why is fishing often an important activity in eastern Asia? Where is it most highly developed? Why? Why is fishing less important in China than in Japan?
7. For how long have the fisheries of Newfoundland been known to white populations? What natural conditions make these fisheries so important? How has their importance been recognized in treaties between nations?
8. What is the catch of the Pacific coast fisheries of North America? How early did commercial fishing become important in this region? Where is the industry centered today? Why?
9. Why has the catch of salmon on the Pacific coast of North America decreased in many areas? What steps have been taken to protect the salmon?
10. Describe the disposition of the salmon catch, the markets, and the export trade in salmon.
11. Why are lake fisheries generally of minor importance? Why are those of the Great Lakes an exception to this rule? Why should these fisheries be regulated?
12. Why are the fisheries of Hokkaido so important? Describe a typical Hokkaido fishing village.
13. What is the relative importance of fishing in Newfoundland? In what respects are natural conditions favorable for fishing in Newfoundland? What is the present condition of the fishing industry there? Why?
14. Why is there growing concern over the decrease in the catch of many of our fishes? Illustrate by examples of decrease in the catch of a given species. Why has this decrease not been particularly noticeable in the markets of the world?
15. Why should sea hunting be regulated? Illustrate by the history of the whaling industry.

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Craig, J. A., and Hacker, R. L., "The History and Development of the Fisheries of the Columbia River," *Bulletin* 32, U. S. Bureau of Fisheries, Washington, 1940.

This bulletin, as indicated by its title, supplies a very good description of the salmon fisheries of the Columbia River.

Parkins, E. A., and Whitaker, J. R., *Our Natural Resources and Their Conservation*, John Wiley and Sons, Inc., New York, 1939, Chap. XX.

This chapter consists of a survey of American fisheries, with particular attention given to those of the Pacific coast. It also emphasizes the desirability of a policy of conservation.

Chapter Thirty-Seven

TRANSPORTATION

Transportation and Its Evolution. One of the earliest problems to engage the attention of man was that of moving himself and his material possessions from place to place for, even when he was a primitive hunter only, it was desirable to follow game migrations and to change location with depletion of the local supply of edible wild fruits and roots. Later, when he became a nomadic herder, dependent on domesticated animals, it was likewise necessary to make frequent shifts, with temporary exhaustion of the pasturage. These same movements of man and his possessions are common today among migratory hunters and herders and, added to them, we have the much more extensive circulation of individuals and the transfer of great quantities of the varied products of many lands to satisfy the demands of more advanced sedentary populations. This is a development of recent centuries only. Man's progress, indeed, has been an accompaniment of conquest of distance, for only with development of ability to draw on the resources of many and often faraway areas to satisfy steadily increasing needs, has marked advance become possible. This is because no area, even the most favored, will supply completely all the necessities of modern, civilized populations. Thus "transportation is civilization."

At first, man was limited to the means of locomotion with which he was endowed by nature. Primitive man then went barefoot, as do many native populations of the warmer parts of the earth today, but the possibilities of travel with greater comfort and at more satisfactory speeds is increased by some form of foot covering and by use of supplementary devices. Therefore the sandal, which developed in some areas as a moccasin, in others as a shoe or boot of some sort, was an early invention, the shoe as we know it being introduced in western Europe early in the seventeenth century. Where snows were deep, additional gear such as snowshoes and skis were likewise found of value and, accompanying introduction of the shoe, other devices such as the alpenstock of the mountaineer and the stilt of the inhabitants of the Landes or marshlands of southwestern France came into use. Eventually, ladders and other inventions, including modern elevators, were designed to assist man in lifting himself vertically.

Man as a Beast of Burden. The first beast of burden must have been man himself. Thus the earthen mounds of the Mound Builders which dot the Mississippi Valley must have been piled up by back-breaking toil. The Pyramids also, burial places of Egyptian kings, were built similarly, with 100,000 men employed for 20 years in erecting these celebrated monuments, according to Herodotus.

In relatively undeveloped regions, man is still a bearer of burdens, for the hunter and trapper must frequently pack in supplies, and among primitive populations, the women not only sling their babies on their backs, but they are likewise carriers of loads of other sorts. (See Fig. 15.) In the tropics, even where advance is greater, produce is frequently transported to market in baskets balanced on shoulders or heads, and other loads may be carried in similar fashion. Even in civilized countries of the Western world, man is still a burden bearer, it being common practice in the erection of smaller buildings for bricks and mortar to be brought to the brick layer in hods and, in similar fashion, mortar to tilesetters and plaster to plasterers.

In the Orient, the use of human burden carriers is common, for population is dense, labor is abundant, and wages are so low that man can

FIG. 353. Transportation in Osaka, the second largest city in Japan, before the war. In this setting of modern buildings, not only are street cars, automobiles, and bicycles in evidence but, to the right, a ricksha and a cart. The latter, loaded with bales, is pulled by two men and pushed by a woman. This was a common sight on the streets of even the largest cities of Japan before the war.

often compete successfully in moving goods. Thus in Japan crushed rock may be unloaded by men and women using baskets, rather than by machinery; and in China coolies may transport goods, suspended from the ends of poles slung across their shoulders, for many miles on the highways. Carts and goods wagons may also be pulled and pushed by human beings rather than by domestic animals, both in the country and in the largest cities; rickshas and sedan chairs may be used to transport passengers; and wheelbarrows, both freight and passengers. In these latter cases, however, man serves as a draft animal, not a burden bearer.

Animals as Beasts of Burden. Man has pressed several animals into service for the transport of either himself or his possessions. These include horses, donkeys, mules, elephants, camels, reindeer, dogs, oxen, llamas, and some others of limited local importance. However, though thousands of years have elapsed since the first use of such animals, there has been little if any change in the list and all still serve essentially the same purposes as at a much earlier date, except as mechanical means of transport have decreased their relative importance. Further, for certain special uses, no adequate substitutes for these animals have been developed as yet.

The horse is man's most important beast of burden. Probably first domesticated in central Asia, where native to the steppe grasslands, use of the horse spread westward gradually, reaching the Americas with the coming of the Spaniards. Up to the beginning of the eighteenth century, the most important means of moving merchandise overland was by pack horse, and this is still true in many frontier areas. Again, during the period prior to the use of carts and coaches, the only practicable means of travel by land, except on foot, was by horseback, as it still is today in many sparsely populated parts of the world.

Donkeys have long been employed, both as saddle animals and for the carriage of goods. Though of small size, they are valuable because of their ability to use poor pasturage to advantage. Probably descended from the Somali ass, they were much used by ancient populations of regions bordering the Mediterranean. From these areas, their use spread westward and into the New World, where they today still find employment as pack animals by mining prospectors in dry areas.

FIG. 354. A Chinese wheelbarrow, here being used to transport both freight and a passenger. (Courtesy of the Philadelphia Commercial Museum.)

The mule, a cross between the horse and the ass, is a very useful animal in warm countries. First known in Asia Minor during very early times, both Greeks and Romans later used them extensively. Frequent references to them are encountered in the Old Testament, as in II Samuel xiii:29, from which it would be inferred that only important personages could afford to own and ride them at that time. Today, however, they are in common use in many parts of the world, both as pack and draft animals.

Employment of elephants as beasts of burden goes back at least to the time of Hannibal, for he used them in his wars with Rome, but today the areas where they are important as work animals are restricted to southern and southeastern Asia, where they are employed to handle heavy timbers in the forest industries, for hunting tigers in the jungle, and to carry passengers in state and other processions.

The camel, domesticated as early as 6000 B.C., is especially valuable as a beast of burden in deserts because of his ability to go without water or food for several days, satisfying his needs during that period from water stored in the reticulum or "second stomach" and fat in the hump. His cushioned feet are also an advantage in travel over dry sand, and his nostrils can be closed so that he does not suffer from desert storms which would be detrimental or even fatal to other beasts of burden. Camels, however, do not provide speedy transportation, for even racing types make no more than 8 to 10 miles an hour and, for ordinary breeds, the rate is 3 miles or less. Further, the surly disposition of the animal leaves much to be desired.

In the frozen north, still other animals are pressed into service. Among the Lapps of northwestern Europe and other populations of northern Siberia, for example, reindeer are in common use, for this animal can find forage where the domestic animals of lower latitudes would starve, and he can also withstand low temperatures. Even though small, he is able to carry loads of 150 pounds or more and, in addition, he supplies food and material for clothing. So important is the reindeer among the Lapps that wealth is measured by the size of the herds owned. In cold areas, dogs are likewise sometimes used for carrying small loads, though more frequently as draft animals.

Oxen have also served to transport goods in times long past, for reference is found to such use in I Chronicles xiii:40; in Africa, they have occasionally been employed as saddle animals. On the Plateau of Tibet, 20,000 feet above sea level, the yak, a member of the ox family, finds similar uses; and on the Andean plateaus, the llama, likewise able to live at great elevations, is a common pack animal.

During the period when travel was largely on the backs of animals, journeys were restricted and time-consuming, made with considerable hardship, and often dangerous as well, as they are today where such means of travel are still important. Transport of goods was likewise slow, expensive, and risks of damage and loss in transit were always present. Further, movement of goods was small and afforded employment to only limited numbers.

Transportation without Wheels. Transportation without wheels developed at a very early date, for the advantages of having men or animals draw rather than bear the burdens were apparently realized during relatively early stages of human development. One of the most striking examples of transport of enormous quantities of material without the use of wheels is afforded by movement of the 90,000,000 cubic feet of rock, some in blocks of enormous size, required to build the Pyramid of Cheops. Most of this stone was apparently transported at least 30 miles; some as much as 500; all by floating some of the distance on rafts and by dragging over prepared

FIG. 355. Hunters of the North Baikal district of the Buriat-Mongolian Autonomous S.S.R. leaving the Evenk hunting collectives for the taiga or forested region on a hunting expedition. (Courtesy of Sovfoto.)

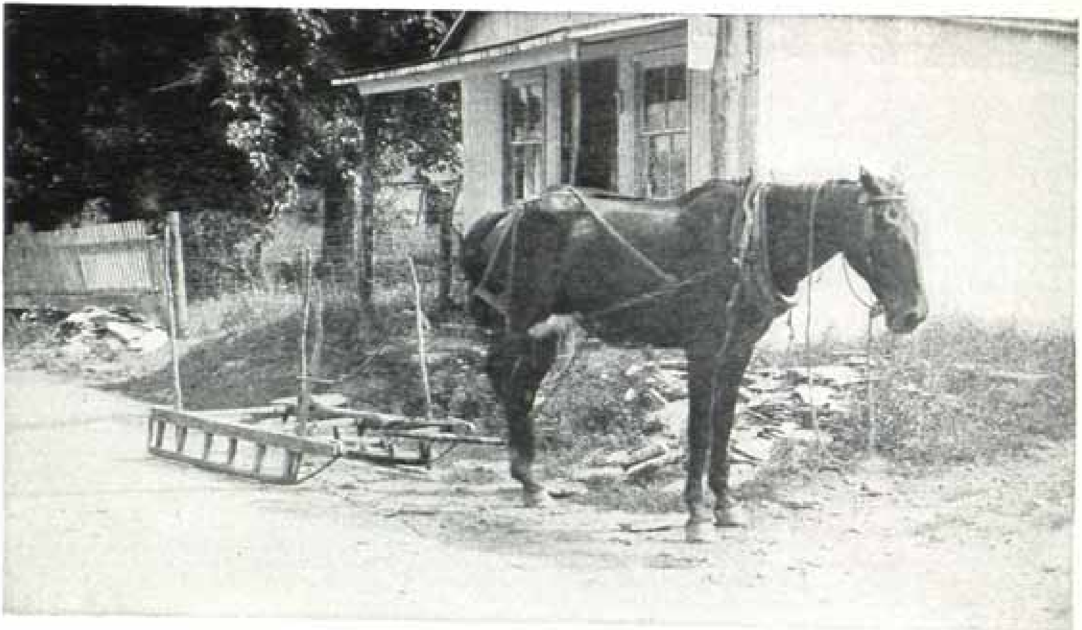

FIG. 356. Calling for the mail in August, Flingville, Kentucky. In this hilly section of central Kentucky, a part of the Bluegrass region, roads are so poor that sleds are often used most of the year for many purposes.

surfaces at least part of the way by thousands of slaves.

When carts were not so common as they are today, sledges were frequently employed on farms in western Europe to move crops from the fields to storage. In parts of southeastern Asia, where the ground is often wet and soft at times of harvest, they still serve that same purpose. In the United States as well, where roads are hilly and poor and use of wheeled vehicles is not always practicable, they likewise find employment at all seasons; during winter months, when the ground is covered with snow, their use is widespread, even where carts and wagons meet the needs of summer transportation.

Sledges of various types, of course, are in use throughout the year for overland travel in the frozen north, where the ground is covered with snow, either all or most of the time, and other vehicles would be valueless. Thus they afford the common means for such travel in much of northern North America and Eurasia. In Eurasia, they are generally drawn by reindeer; in North America, commonly by dogs. Such sledges have been very valuable, not only to native populations, but to polar explorers as well.

Evolution of Wheeled Vehicles. Movable rollers were often employed in early transport to lessen friction between the sledge and the surface over which it was drawn. This is known from study of the wall paintings of Egyptian monuments. Later, rollers were attached to the bed of the sledge which supported the weight to be moved. Thereafter, it was probably only a short time before it became apparent that rollers could be replaced to advantage by circular slabs, connected by an axle. Such was the origin of the modern wheel, one of the most important devices ever invented by man. When it occurred, we do not know exactly, though it is generally thought to have been between 4000 and 1500 B.C. Whatever the exact date, its invention and use marked an important step forward in means of transportation.

The first wheels were solid disks, probably of small size, attached firmly to an axle, so that both wheels and axle revolved. This is still common practice in some parts of South America, and for use on cars which operate on fixed tracks. Later, as a means of surmounting obstacles more easily and decreasing friction, the size of the wheels was increased on many vehicles, and differences in the wheel sizes in the front and rear developed with introduction of wagons, for this made

shorter turns possible. Further, since wheels fixed on axles have disadvantages in turning corners, it was not long before stationary axles, with independent, freely revolving wheels, came into common use in most parts of the world. The present-day dished wheel with spokes is the final result of a gradual evolution from these original ventures in improvement of means of transportation.

Wheeled vehicles, both chariots and carts, were in use in Egypt at a very early date and, from paintings and sculptures, we know what they were like, particularly the chariots. From Egypt, their use spread to other Mediterranean countries, where subsequent change and improvement in them occurred. Chariots apparently preceded carts in western Europe, for the latter were not known there until about 1000 A.D., though chariots were in use much earlier. Despite a gradual improvement in vehicles, however, even as late as 1200 A.D., the body of British carriages rested directly on the axle, and the discomforts of travel in them must have been great on the miserable roads of that time. About the middle of the sixteenth century, these early carts were supplanted by wagons which carried both freight and passengers and, still later, by coaches and stages; but it was not until 1804 that

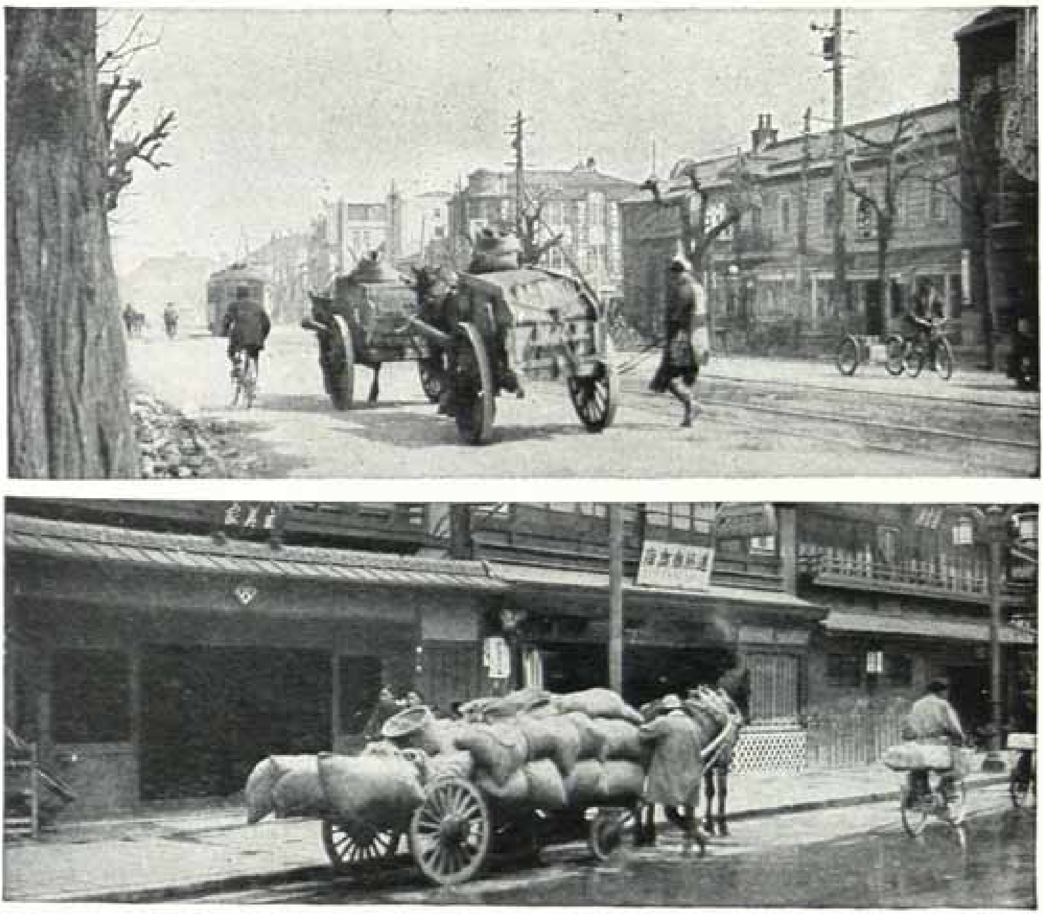

FIG. 357. *Top:* Loaded carts on the main traffic street of Sapporo, the capital of Hokkaido. The substantial construction and large wheels of these carts make them adapted for use on poor roads. Similar carts are in use throughout North China, where roads are likewise poor.

Bottom: A four-wheeled wagon with very small front wheels, on Sanjo Street, Kyoto, Japan. These small wheels permit the wagon to turn within its length, necessary where roads are often very narrow, as in Japan.

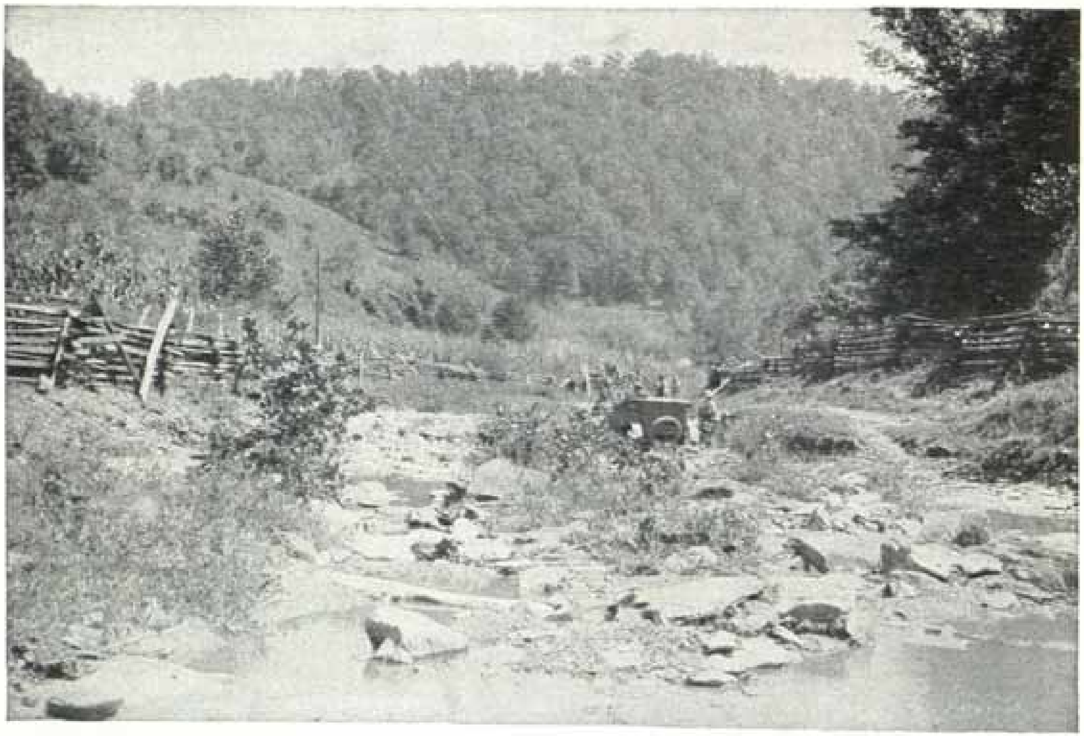

FIG. 358. Roads up the smaller creek valleys are everywhere poor in the Kentucky Mountains, even today. The road up the valley of Meatscaffold Creek, Breathitt County, shown above, is located in the creek bed, between the fences which separate the small amount of level land in corn from the highway. Under such poor road conditions, travel, except on foot or on horse or muleback, is difficult.

springs were invented, and even for some time thereafter they were not in general use. The steady improvement of vehicles tended to increase both travel and movement of goods, which afforded employment for somewhat increased but still not large numbers, because highways remained poor.

Highway Development. Roads bear somewhat the same relation to a country that the circulatory system does to the human body, for they make possible the flow of trade which nourishes communities and their urban centers, much as the flow of blood does the different parts of the human body. In the absence of good roads, communication becomes difficult; isolation is the rule; and ideas diffuse slowly. These effects of their absence have been illustrated in earlier chapters by discussions of living conditions in the southern Appalachians.

The first great road builders were the Romans, who realized that, without effective means of communication, it would be impossible to establish their empire on a substantial basis. However, though their highways were designed primarily for military use, they were likewise of benefit in facilitating trade. The Roman roads were of different classes and types, but they were always well drained, with substantial foundations, and of adequate width. All were surfaced and some were even paved with squared blocks of stone. So substantial was their construction that sections of some of them are still in use. Marked with milestones indicating distances to Rome, these highways remain an impressive monument to the ability of the Romans as highway engineers.

For hundreds of years after the fall of the Roman Empire, there was no comparable construction of roads in western Europe. After the decline of Rome, indeed, the older roads fell into disrepair and for many centuries they went from bad to worse. Therefore, during this long period, only small loads could be moved and costs of products hauled were high. Under such

conditions, local raw materials often could not meet the competition of imports at seaboard because of the difficulties and costs of transport by land. Not only was movement of goods difficult and slow, but it was often dangerous as well, for bands of highwaymen preyed on traffic and often murdered travelers and traders. Roads were so poor in England in the middle of the seventeenth century that 800 horses are reported to have been captured by Cromwell's forces, "while sticking in the mud." When a long trip was contemplated at that time, it was a common practice to send servants ahead to locate the most promising route, for roads were sometimes submerged for considerable stretches and travel across fields under guidance became necessary. Under such conditions, travel was necessarily slow, sometimes not much more than 1 mile an hour.

Similar conditions existed in the United States until long after the American Revolution. In the earlier days of the preceding century, for example, an overland trip from Boston to Washington, D. C. was a real adventure. At that time, travel on foot by many roads might actually consume less time than when attempted by use of wheeled vehicles. Thus, during that period, waterways were preferred to highways; west of the Appalachians, they were the only effective means of moving freight.

In road construction of early days but slight attention was paid to the foundations and both drainage and surfacing were generally inadequate. The first to recognize the importance of making road surfaces waterproof were Telford and McAdam, the latter giving his name to the type of road known as "macadam" about 1830. Built on adequately drained foundations of crushed rock and surfaced with finer material compacted by rolling, such macadam roads are a great improvement over those with dirt foundations only, with possibly a surfacing of stone imbedded in the underlying soil.

The building of any considerable mileage of good roads in the United States dates from the advent of the automobile, for the effective opera-

FIG. 359. An unimproved road near Brookings, South Dakota, about 1904. Such roads imposed great limitations on travel and fastened isolation on the rural districts. (Courtesy of the Public Roads Administration.)

FIG. 360. A superhighway, the Pennsylvania Turnpike, looking east at the Bedford Interchange, midway between Harrisburg and Pittsburgh, where direct connection with United States Route 220 is made, about two miles north of Bedford. (Courtesy of the Pennsylvania Department of Highways.)

tion of which continuous stretches of hard-surfaced highways are necessary. Therefore, since the turn of the century, accompanying the greater use of motor cars, there has been an enormous increase in the number of miles of all-weather roads. They are likewise being built wider, with heavier surfacing, and cement is winning increased favor for construction, with the greater demands imposed by the steadily growing loads hauled. Each year we now spend well over $1,000,000,000 for their building and maintenance.

The newer main highways are commonly 100 feet wide and have at least two traffic lanes; occasionally they reach widths of as much as 200 feet, with four or more lanes. Some of recent construction, like many of the earlier highways, are toll roads, for the saving in time, fuel, and wear may more than offset the charges levied for their use. An outstanding example of these newer highways is the Pennsylvania Turnpike, which extends east 159.6 miles from Irwin, a few miles east of Pittsburgh, to Middlesex, a few miles west of Harrisburg. Its construction was designed to facilitate the flow of traffic by elimination of curves, grade crossings, and the barrier of the Appalachians. This was accomplished by building 110 miles of straight highway; 50 miles of easy curves; by-passing all towns; elimination of all road, street, and rail intersections; and construction of 6.7 miles of ventilated tunnels, which save 9000 feet of vertical climb. Except in the tunnels, where but two in number, there are four traffic lanes, with additional short, parallel, paved roadways to allow admission of interchange traffic from intersecting main north-south arterial highways, as shown in Fig. 360. This likewise shows the provision made for parking cars off the pavement. Built at a total cost in excess of $70,000,000, this is a toll highway, the charge for operating a passenger car over its entire 159.6 miles being $1.50 and, for the round trip, $2.25. Smaller tolls are levied for shorter distances. The Pennsylvania Turnpike has proved very popular, travel now being over 10,000 vehicles each Sunday, and heavy at other times. In fact, it has been so successful that plans are being made for its extension east to Philadelphia and west to the state line.

Each year witnesses construction of additional mileage of new and better roads, though even in the prewar period we had 50 per cent of all surfaced highways, on which operated 75 per cent of all automobiles in the world. In all, there

FIG. 361. *Top:* Part of the Manhattan connection of the Triborough Bridge project, with the East River Drive at the right, looking toward midtown skyscrapers. In the foreground is the Bronx; ahead to the left, the Borough of Queens.

Bottom: The two-level concrete-paved East River Drive, with a third level serving as an esplanade. (Photo by McLaughlin Air Service, Courtesy of the New York City Department of Parks.)

were more than 538,328 miles of state highway, with 80 per cent of this mileage surfaced, in addition to 2,535,777 miles of dirt roads, most of which are fully as good as some of the so-called "automobile roads" in many other parts of the world such as China.

In addition to the Pennsylvania Turnpike which has been described, we already have 400 miles of thoroughly modern highways in the New York metropolitan area; Los Angeles and Pasadena are linked by the Arroyo Seco Parkway and Los Angeles has the Cahuenga Pass Freeway; San Francisco has a system which includes the San Francisco Bay and Golden Gate bridges with their approaches. Farther east, Chicago's best example of a thoroughly modern highway is the Outer Drive; Detroit's, the Woodward Avenue superhighway; and Cleveland's, Bulkley Boulevard.

It is now proposed to improve our existing system of overland transportation by construction of a 34,000-mile network of express highways at an estimated cost of $35,000,000,000, with the work to be spread over a period of from 10 to 20 years. These highways are to be 300 feet wide, with four traffic lanes, no cross traffic, no heavy grades, no sharp curves, and an unobstructed view ahead of at least 800 feet. As planned, belt lines will allow cities to be by-passed if desired; in the cities, the highways will be either elevated or depressed, preferably the latter. Highway terminals will also be provided in the larger urban centers, with near-by, privately operated parking garages. If carried through to completion, this construction will produce a revolution in transportation.

In China, by contrast with conditions in the United States, there are, even by the most liberal estimates, only about 40,000 miles of automobile roads and, for the entire population, but 45,000 cars. This number includes trucks, motorcycles, busses, and all other gasoline-propelled vehicles. This is only about one car for each 10,000 persons. In China, most roads are still narrow and poor, much as they were in this country many years ago.

Modern highways are not only useful in times of peace, but they are also of great importance in times of war and, in Germany for one country, they have been deliberately constructed for military use, much as in the days of the Roman Empire. The same is true for some of the great

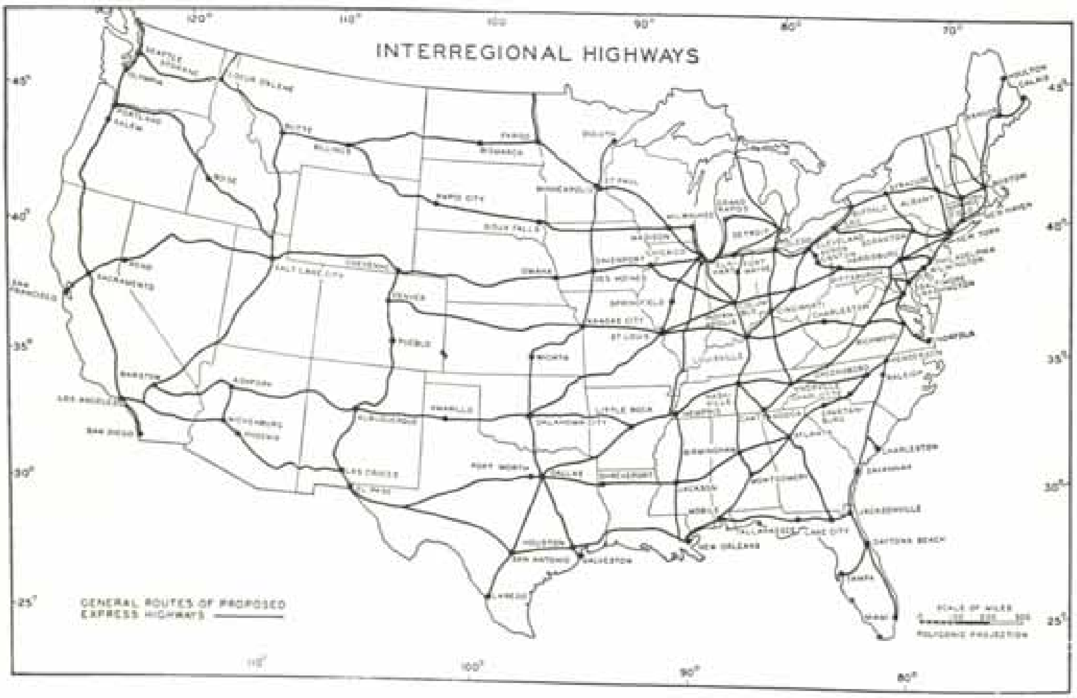

FIG. 362. A proposed express highway system for the United States.

FIG. 363. The old Chesapeake and Ohio Canal, with tow paths on either side. Though carrying much freight during its early history, it is today used but little, for it has been supplanted by the rail line which here parallels its course in the Potomac Valley. (Courtesy of the Baltimore and Ohio Railroad.)

highways of India, particularly those of the northwestern frontier.

River and Canal Transportation. The possibility of utilizing rivers for transporation must have been discovered very early in the history of the human race, and logs and rafts must have served to aid travel and for moving freight in very ancient times. Even use of canals or artificial waterways is of long standing, for they were employed in both Egypt and China at least several hundred years before the time of Christ. It is believed, for example, on the basis of reports by both Herodotus and Strabo, that the Egyptians cut a canal to join the Nile and the Red Sea, between 616 and 521 B.C. This waterway was 37 miles long, 100 feet wide, and 40 feet deep, and thus of dimensions to float boats of considerable size. Similarly, the southern part of the Grand Canal, which connects the Yangtze Valley with the North China Plain, was constructed in the sixth century before Christ, and its northern extension was completed early in the Christian era.

For centuries there has been a splendid system of artificial waterways in Holland and many miles of canals in most of the other countries of western Europe. Some of these date back to the time of the Roman Empire; most of them, however, are of more recent construction; and some have been built during the present century. The epidemic of canal building reached its peak during the last part of the eighteenth and the early part of the nineteenth century, when roads were poor and railroads were unknown. Though today of much less importance than at the time of their construction, these early artificial waterways in their

time played an important part in the development of the areas they served, for they were a great improvement over the other means of transportation of that period. Hence their use lowered costs of carriage of goods materially. In fact, it is probable that, except for their existence, the large-scale development of industry which resulted from their use in England would have been impossible.

Movement of goods by canal has the obvious disadvantage of slowness, both because of time lost in passing through locks and the fact that high speeds cannot be maintained, since damage to the banks would result from wash caused by boats in transit. During the period when overland trade was carried by pack animal, cart, and wagon, when land movement of freight was if anything even slower than by canal, this fact was not important and canals met all competition successfully.

In the United States, the canal-building mania occurred a few years later than in western Europe, including Great Britain. Early construction of several short canals along the Atlantic seaboard proved so profitable that the building of longer artificial waterways to link the drainage of the interior with that of the Atlantic seaboard soon followed during the first part of the nineteenth century. The most notable of these longer waterways was the Erie Canal, with the Chesapeake and Ohio also of considerable importance. For a short period, these canals, like those of western Europe, served a useful purpose. During the later years of canal building, however, rail construction and the introduction of steam in transportation made such serious inroads on their business that they fell into gradual disuse. This was true even of those such as the Erie, now the New York State Barge Canal, on which enormous sums were spent for improvement. Rivers likewise fell into increasing disuse as rail transportation extended, and especially as it improved. The history of canal construction and river use has been considered more fully in Chap. XVII, to which the student is referred.

Railroads. The "civilizing rails" are a development of but little more than a century. The first railroads built were designed to move coal from the mines to water highways in England; their function as passenger carriers developed somewhat later. Prior to their construction, coal had been transported, first by pack animals, then by

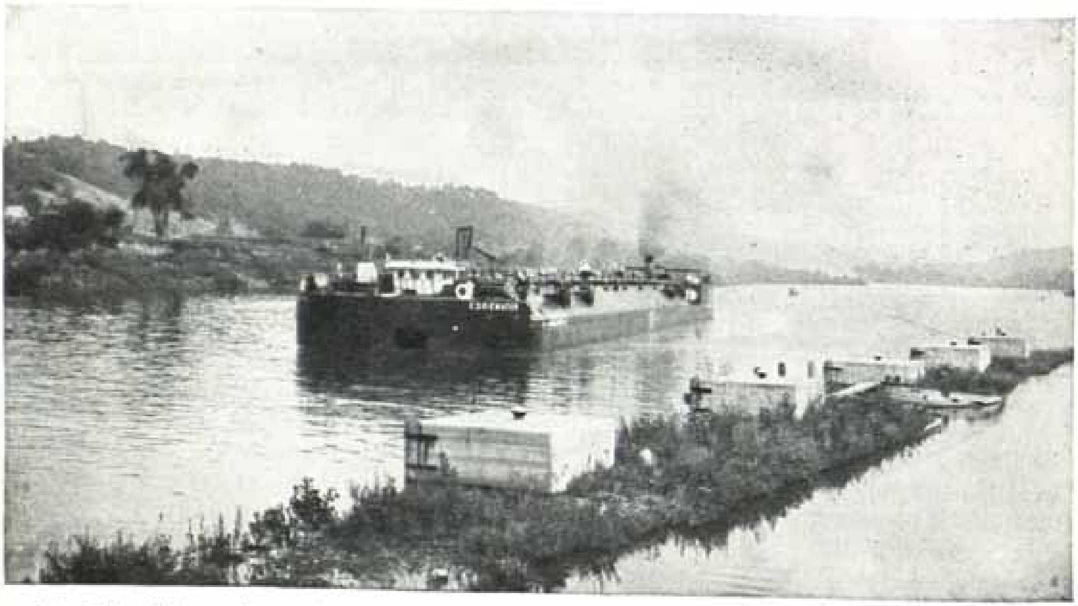

FIG. 364. The steel motorship *Edgewater,* loaded with 2000 tons of Lake Erie gravel, en route to New York City, on the New York State Barge Canal, the modern successor of the old Erie Canal. Even after extensive improvement at enormous expense, the present canal carries relatively little freight in normal times, for it must meet rail competition. (Courtesy of the New York State Barge Canal Commission.)

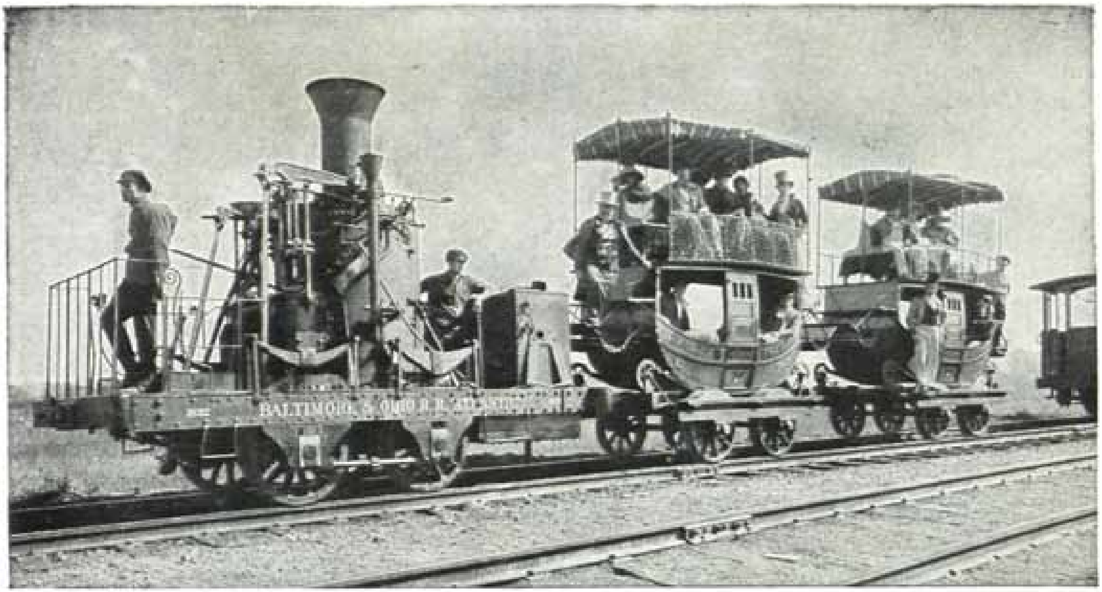

FIG. 365. The "Atlantic" locomotive of 1832 and the coaches built by Richard Imlay, the Pullman of his day. This was the first locomotive to enter the nation's capital, in 1835. Trains of that time operated on strap-iron tracks fixed to wood rails; those shown above are the rails of today. (Courtesy of the Baltimore and Ohio Railroad.)

carts, and later by wagon. But even with these improvements, hauling costs remained high. To reduce them, wooden rails were introduced; later, to decrease wear, these were protected by strap iron; and, in 1794, short cast-iron rails were installed. Despite these changes, animals still furnished the motive power and it was not until 1804 that an engine was used, even experimentally. The first of these early locomotives to prove commercially successful was that of Stephenson, which was tried out in 1814. With subsequent improvement, this became the father of the modern locomotive. The first railroad, the Stockton and Darlington line, was opened in 1825, but this was used only for carrying coal. By 1834, however, passenger traffic had been inaugurated and thereafter rail construction spread rapidly.

Development of railroads in the United States paralleled that in Great Britain. The first cars operating on rails, used in hauling both freight and passengers, were drawn by horses; not until May 21, 1830, was steam used for motive power. This innovation was prompted in part by favorable reports from England and by waterway competition, particularly that of the Erie Canal, opened in 1826. The first locomotives were but little superior to horses for motive power. In fact, in a race between "Tom Thumb," the first American locomotive built, and horses, the latter won. Nevertheless, the race demonstrated the value of the locomotive to an extent that the potential superiority of steam was recognized, and shortly thereafter it displaced other forms of motive power on American railroads.

From these small beginnings has developed the present railroad system of the United States, still the primary reliance for travel and transportation by land, except for short distances or under specially favoring conditions. From 23 miles in 1830, railroad mileage increased to 2818 by 1840, and to 9021 by 1850, at which date all except 80 miles in Louisiana were east of the Mississippi River. Then, as railroads were extended westward and gaps in the eastern systems were closed by additional construction, mileage nearly doubled each decade until 1890, by which time there were 163,597 miles, not including parallel, yard, and siding tracks. The maximum mileage, excluding double trackage, was attained in 1930, with 249,052 miles in all. Since that date, there has been a loss, if double trackage is ex-

cluded. At the beginning of 1940, the total mileage had dropped to 235,064, as a result of earlier overbuilding and the competition of new forms of transportation. Despite this fact, there is no equivalent set of rails elsewhere in the world.

Accompanying this growth of mileage, American railroads have improved steadily and increased in efficiency. In 1939, they moved 34,102,759 cars and 1,636,215,034 tons of freight 333,438,412,000 revenue ton miles. During the same year they also carried 450,372,553 passengers 22,641,334,222 passenger miles. During the war, despite critical shortages, even these remarkable records were surpassed. The speed of freight trains has stepped up steadily; for example, it is today 62 per cent higher than it was in 1921. This speeding up of freight movement saves business millions of dollars each year in inventories alone, and this benefits all. At the same time, both freight and passenger rates have decreased, which results in other savings. Unfortunately, as a result of increased labor and material costs, this trend has been interrupted, at least temporarily.

Passenger service has also been bettered. On the first rail lines, travel was slow, uncomfortable, and dirty. Each decade, particularly of late, has witnessed some elimination of these former objectionable conditions. Roadbeds have improved; in many cases, rails are now welded in mile-long sections which makes it impossible to measure train speed by counting wheel clicks at rail joints. Both make riding smoother, as well as having other advantages. Only a few years ago, passengers closed all car windows and doors and endured as best they could, and engine crews provided themselves with wet sponges to protect their lungs from smoke and gases in tunnels; today, this is no longer necessary where electrification has occurred.

The most recent improvement is the use of Diesel-powered locomotives, a development of the past 15 years. These power plants move air-conditioned, closed tubes of stainless steel, with double-paned, hermetically sealed windows of shatterproof glass, which whisk passengers across the country at speeds undreamed of in the early days of railroading. Only 115 years ago, it took John Quincy Adams 45 hours to travel from Washington to New York and required six changes en route. This was rapid travel at that time. Today, one can make the same trip 226½ miles any day in slightly under 4 hours at a cost of less than $5.00.

In addition to hauling passengers, Diesel-powered locomotives have also found general acceptance in many switching operations because of their low costs for operation and maintenance, and because smoke is objectionable in cities. Modern freight trains no more resemble those of the past than do those which carry passengers. Engines have increased in power, cars in size, and trains have grown in length. Pickup and delivery services have been instituted to serve shippers; livestock in transit is fed and watered; and hogs may even have shower baths on hot days, by use of sprinklers on sidetracks.

In considering our rail lines and their future, it is well to bear in mind that, despite development of improved highways and other means of transporting passengers and moving freight, the railroads still constitute the backbone of our transportation system. Therefore, in planning effective means for keeping the lifeblood of industry moving, they should be accorded the position to which they are entitled by their importance.

With development of navigable interior waterways, improved roads and rail lines, particularly of the latter two, transportation has become an important economic activity, employing large numbers of workers, both directly and indirectly. For example, development of the automobile industry in the United States, made possible by improved highways, gives employment to several million workers in occupations unknown less than 50 years ago. The rapid extension of rail lines during the last three-quarters of the nineteenth century functioned similarly during the preceding 50 years, and it is probable that the last half of the twentieth century will bring changes which may have even more far-reaching effects than any which have occurred up to the present.

Mechanized Road Transport and the Modern Motor Car. Extensive mechanization of road transport characterizes the third important and latest stage in the evolution of land transportation. The first began with invention of the wheel and its application to carts and wagons; the second, with use of the steam locomotive on railroads; the third, with mechanical propulsion of vehicles on highways, development of the present-day automobile, and construction of systems of surfaced roads.

Fig. 366. *Top:* A modern streamlined train, the "Capitol Limited," crossing the Potomac River at Harper s Ferry. This all-Pullman train, which operates overnight between Chicago and Washington, is hauled by a twin unit 3600 H.P. Diesel-electric locomotive. (Courtesy of the Baltimore and Ohio Railroad.)

Bottom: A modern freight train en route to the coal pier at Lambert Point, Norfolk, Virginia. On arrival at the "dumper" at the pier, the cars are lifted mechanically and their contents dumped into the holds of vessels at the rate of 2000 tons an hour. (Courtesy of the Norfolk and Western Railway.)

The first mechanically propelled vehicles to be operated on highways were powered by steam engines, experimentally as early as 1769, and commercially in England by 1830. Though some of these attained speeds of 12 to 15 miles an hour and were able to carry as many as 15 passengers, they were unable to meet rail competition successfully, partly because of the poor roads of that time. Mechanized highway transportation therefore did not assume importance until much later, with invention of the internal-combustion engine and its adaptation for automobiles. By 1885, Carl Benz had built the first successful motor car in Germany, and Panhard followed shortly with a second in France; soon others were built elsewhere. Production of these cars represented the beginnings of the automobile industry in Europe.

At about the same time, American inventive genius was experimenting with horseless carriages, and by 1900 a considerable number were operating on the roads. Though these were the forerunners of the present streamlined product, they were a strange and heterogeneous lot, for each represented what its inventor thought a motor car should be. Patterned after the carriages of that day, some retained the curved dashboard of the buggy, even though not the socket for the no-longer-needed whip. All had so much road clearance that it was easy to "get out and get under," frequently necessary in those days. Some were powered by steam, others by storage batteries, but most of them used gasoline engines. Both chain and gear drives were employed, for the motor car was in its experimental stage, with bicycle-repair men, machinists, engineers, and amateurs testing out ideas. Sometimes these cars ran at fair speeds and sometimes they refused to move; when they operated, they heralded the fact audibly.

In those days, even the most used and important roads were generally poor. Over portions of the main highway between Detroit and Chicago, for example, there were many stretches where speeds in excess of 6 to 8 miles an hour could not be maintained without disaster. Because of the frequent deep ruts in these earlier roads, it was necessary to use wheels of large diameter and to have considerable road clearance. However, as ownership of cars increased, public demand forced highway improvement and development of our present network of hard-surfaced roads.

Much of the earlier experimentation with "horseless buggies" occurred in the Middle West, particularly in southern Michigan and immediately adjoining areas. Thus the present industry, which originated from these small beginnings, is still concentrated in that region, with Detroit as its center. Though the automobile industry was not an offshoot of earlier industries but an independent development, with increase in its importance and decline in that of the manufacture of carriages and their parts, many factories were converted to produce wheels, bodies, and parts for automobiles, and some even embarked on the manufacture of complete motor cars. In connection with the manufacture of automobiles, production of other types of motor-driven vehicles such as busses and tractors of various types developed somewhat later, generally in separate plants, but quite commonly under the same management.

Concentration of the automobile industry in southeastern Michigan worked great change in that part of the state, particularly in the urban centers. Detroit, a pleasant residential city of only 285,704 inhabitants in 1900, almost doubled in size during each decade up to 1930, by which date its population was 1,568,662. During these same decades, some of its suburbs grew even more remarkably, with the result that the present population of metropolitan Detroit is approximately 2,000,000. During this period of rapid growth, what had earlier been farm land was shortly within the city limits, and fields and pastures gave way to private residences, apartment houses, stores, and office buildings. Flint, Pontiac, Lansing, and other near-by urban centers enjoyed equal or even more phenomenal growths. Flint, for example, with a population of only 13,103 in 1900, became a city of 156,497 inhabitants by 1930.

The advent of the automobile worked great changes in transportation during this same period, 1900 to 1930. Short-haul passenger traffic by rail disappeared almost completely, destroyed by the greater convenience and flexibility of private automobiles and commercial bus lines. Moreover, the busses, which increased steadily in numbers, size, and comfort, cut into the longer hauls as well, for within recent years it has become possible to travel almost anywhere by busses which operate on regular schedules from well-equipped terminals at rates the rail lines cannot meet, because they must acquire and maintain a right of way. Interurban lines also lost such a large fraction of their revenue that many were forced into bankruptcy, and streetcar lines were affected to the extent that most of them operate with little or no profit in normal times. Not only did bus lines and private cars affect passenger traffic, but trucks operating on the improved highways made serious inroads on rail revenue derived from hauling freight, in fact to an extent that the rail lines have in many cases added trucks to their equipment to recapture the business. It is well to remember in considering the benefits derived from hauling by truck, that these are made possible only by highways built and maintained by the taxpayers, in other words, that the trucks are subsidized by the state.

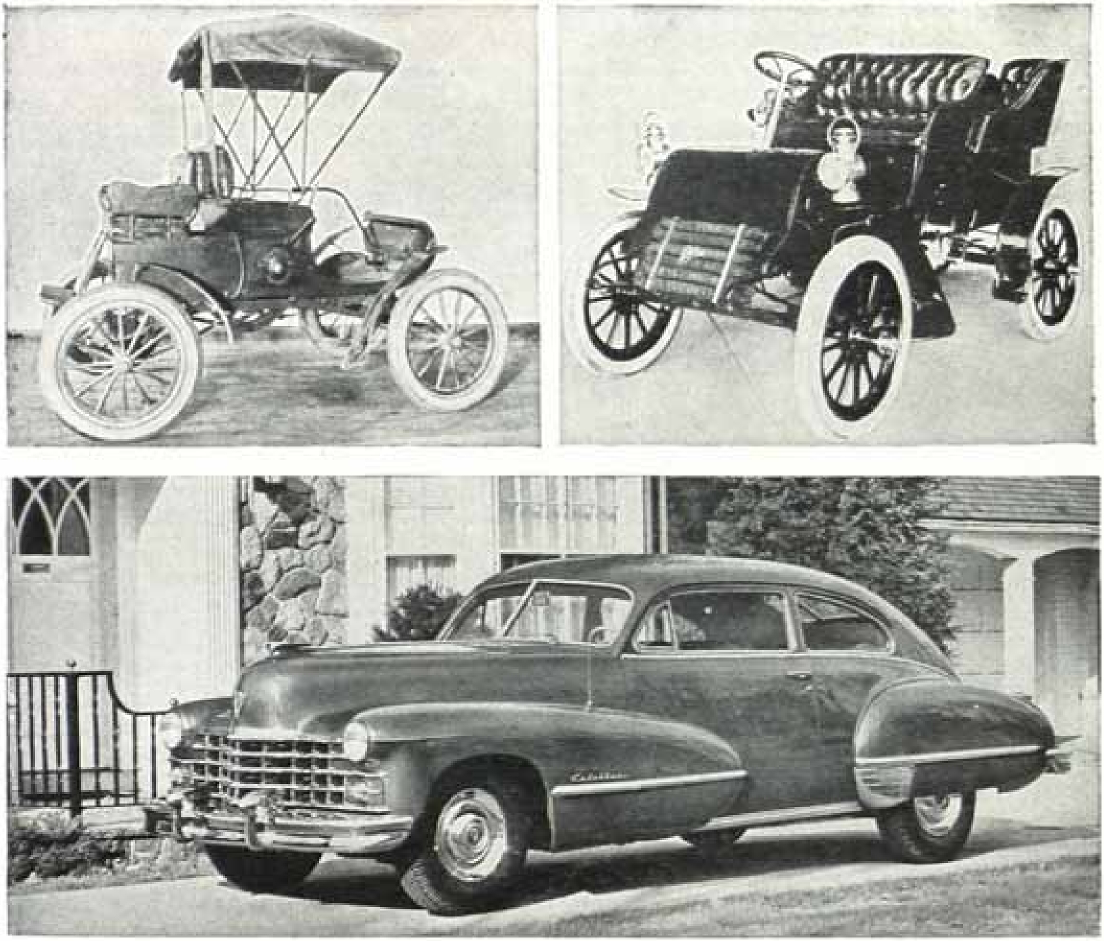

FIG. 367. Three stages in the evolution of the modern motor car. The 1901 chain drive Oldsmobile shown above was essentially a buggy powered by a motor, even down to its body with a curved dash, but the 1902 Cadillac at its right shows indications of departure from this earlier design. In the 1947 Cadillac at the bottom, resemblance to the buggy has disappeared completely. (Courtesy of the General Motors Corporation.)

Ocean Transportation. When man first put out to sea in ships is uncertain, but navigation of coastal waters, with sailings from headland to headland, occurred very early, certainly long before the birth of Christ. By the time of the Phoenecians, a people living at the east end of the Mediterranean, long sea voyages had become relatively common, for these people visited Britain and are supposed by some to have circumnavigated Africa. Among the Greeks and Romans, though used more for war than commerce, vessels propelled by oars and driven by sails were likewise employed in carrying seaborne trade. During this same period that navigation was developing in the quiet waters of the Mediterranean, the populations of northwestern Europe were also taking to the stormier seas of the North Atlantic and making extended voyages, assumed by some to have carried them even to the shores of the New World.

Following discovery of the New World by Columbus in 1492 and rounding of the Cape of Good Hope by Vasco da Gama, who reached India May 20, 1498, new opportunity for development of sea-borne trade opened up and commerce increased rapidly. During this early period of ocean navigation, however, vessels were all small and driven by sail. Even the cele-

brated East Indiamen, the finest vessels of about 1840, did not exceed 1500, with many not more than 1000 tons in size. They also had buff bows and heavy sterns which made them slow sailers. To remedy this shortcoming, American shipbuilders designed the clipper, the first boat of this type probably being the *Rainbow*, launched in 1845. These vessels made much faster time because of the shape of their hulls, the *Great Republic*, launched in 1853 and one of the largest sailing ships ever built, making the crossing from Sandy Hook to Land's End in 13 days. The days of supremacy of the clipper, however, were short, for they were soon driven from the seas by the more efficient steamship.

The first to achieve commercial success in attempts to use steam for the propulsion of ships was Robert Fulton, whose *Clermont* made the round trip from New York to Albany, a distance of 300 miles, in 62 hours in 1807. These early steamships were driven by paddle wheels, later superseded for ocean-going vessels by screw propellers, though still used on river boats. The honor of first crossing the Atlantic by steam is claimed for several vessels, but whichever it may have been, it occurred about 1825.

All the earlier ships were of wood construction, but it was not long after development of the steamship that the superiority of iron was recognized and, shortly thereafter, vessels increased rapidly in size. During and subsequent to this same period, iron was supplanted by steel, and power plants underwent great change, the most recent development being introduction of the Diesel engine, which burns oil and adds greatly to the effectiveness of modern shipping by requiring less fuel space. Today, 20 per cent of the total ocean tonnage of the world operates with this type of equipment.

Not until conquest of the oceans by cargo carriers of considerable size, able to operate at fair rates of speed, was development of any considerable trade between countries or sometimes even between parts of the same country possible, for freight rates on all hauls by land are and must remain high, so far as can be foreseen at present. Therefore present-day commerce is a development of but slightly more than a century. Cheaper than land transportation because no investment in right of way but only in terminals is required, carrying enormous tonnages with relatively small capital outlay and low labor costs, using a highway which connects all the lands and is open throughout the year, ocean transportation of the present has worked a revolution in our ways of life.

Air Transportation. Man's "conquest of the atmosphere" has been achieved by the use of craft both heavier and lighter than the lower air, each type having certain advantages, but with the former assuming ever greater relative importance.

Balloons were first made practicable for commercial use by discovery of hydrogen, today displaced by helium where available, because of its noninflammability. By 1763, invention of the balloon net, safety valve, and ripcord made possible the flights of the Montgolfier brothers in France. The first passenger flight by balloon across the English Channel was in 1785, but this and other early ventures were made with nonrigid gas envelopes which could not be steered. The earliest rigid-type airships of commercial importance were the Zeppelins, the first of which was built in 1900; in 1929, the 771-foot long *Graf Zeppelin* circled the world. Several of these rigid-type ships were built in the United States, but development of heavier-than-air machines able to fly has diverted much of the former interest from them.

Man apparently attempted to soar with wings in very early times, or he at least contemplated its possibility, for the mythology of many peoples contains tales of flights such as that of Icarus, who drowned in the Icarian Sea, a part of the Aegean Sea near Samos, when he flew so near the sun that his wings of wax melted. Today, what was formerly only a possibility has become a reality with gliders and, even more successfully, by use of the modern airplane. The first to perfect a mechanically propelled heavier-than-air machine were the Wright brothers. Beginning their experiments several years earlier, they flew for the first time on December 17, 1903, remaining in the air 12 seconds. Even as late as 1905, however, people refused to credit it and their flights attracted little attention in the papers. This was because the belief that the "laws of gravitation could not be repealed" had been preached so assiduously by reputable scientists that it was almost impossible to secure a respectful audience for tales of flight by a heavier-than-air machine. In fact, it was not until September, 1918, that the formal demonstration at Fort

FIG. 368. *Top:* The lower end of Manhattan Island and the *America,* a modern ocean liner. To the right is the East River; to the left, the North or Hudson River. In the foreground, the Battery and the Aquarium may be seen, with the towering office buildings of New York in the background. (Courtesy of the American Lines.)

Bottom: Ocean-going freighters of moderate size in the harbor at Tampa, Florida. (Courtesy of the Tampa Chamber of Commerce.)

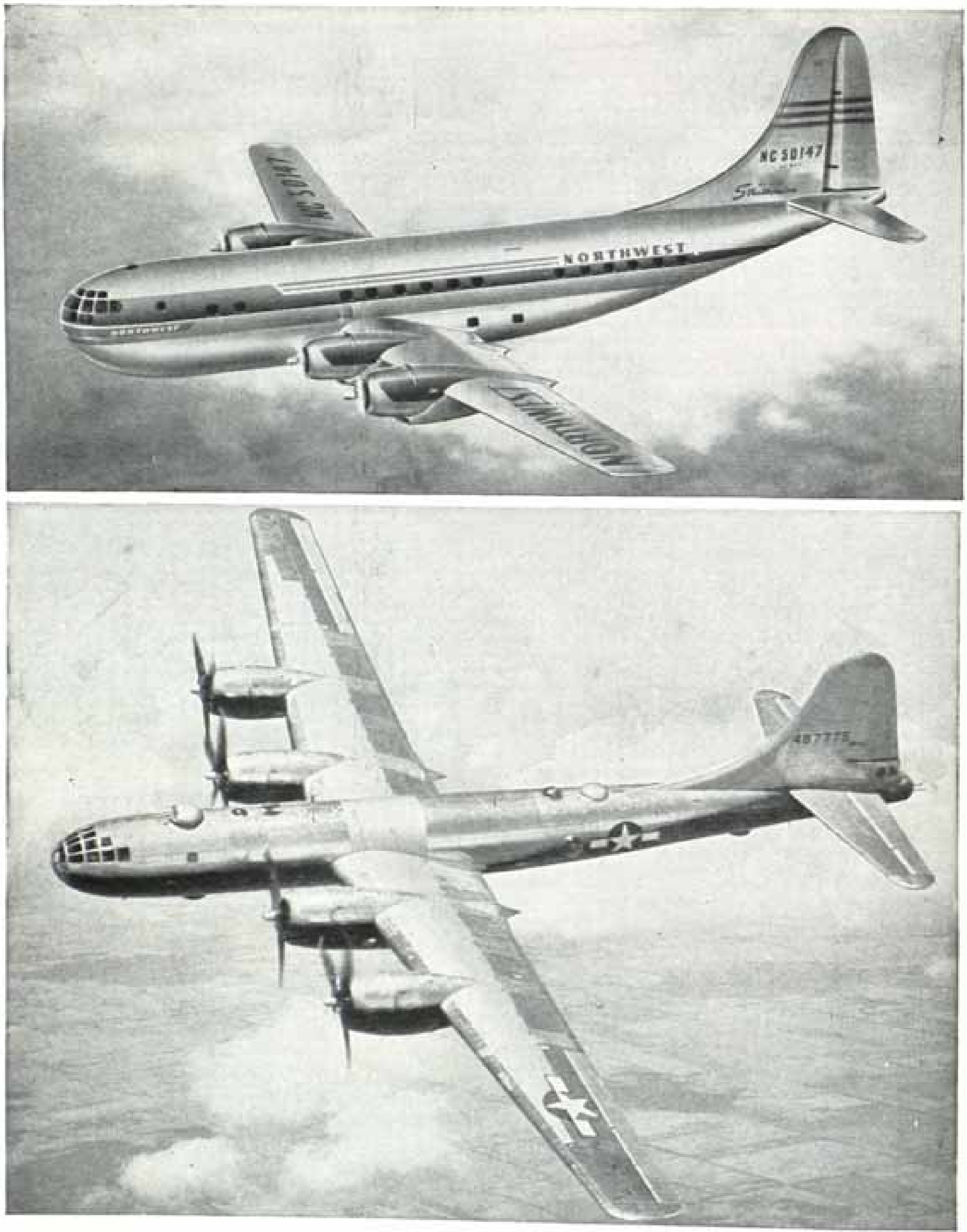

Fig. 369. *Top:* A stratocruiser of the Northwest Airlines, a four-motor Boeing 377 with a wing spread of 141 feet, 3 inches, a gross weight of 135,000 pounds, a cruising speed of 300-350 miles per hour, an operating range of 4200 miles, an operating altitude of 25,000 feet, and a ceiling of 30,000 feet. This low-wing, two-deck passenger transport, with comfortable seats for day and roomy berths for night travel, has standard accommodations for 80 day passengers, or as a luxury sleeper, accommodations for 65 day passengers; 30 berths and 14 lounge chairs. In transcontinental operation, it has a crew of five; in transocean, one of seven. The all-cargo version can carry a load of 39,000 pounds. (Courtesy of Northwest Airlines.)

Bottom: A giant "war bird," the Boeing B-29.

Meyer before a crowd of less than 1000 persons laid at rest all doubt that the "impossible" had at last been accomplished. Since that date, development has been rapid. Today, regular air lines operate between all our larger cities and between them and other parts of the world. Army fliers have crossed the United States from Burbank, California, to La Guardia Field, New York City, in 4 hours, 34 minutes, and 35 seconds. Stratoliners make regular runs from New York to Los Angeles in 15 hours and from Los Angeles to New York in 13½ hours, flying at 19,000 feet or more, where high speeds can be maintained because of the thin air. Not only do lines operate over the land, but over the water as well: between North and South America; across the Atlantic to Europe; and over the Pacific to eastern Asia. Today, Lisbon is less than 10 hours, Moscow is only 23 hours, Buenos Aires 25 hours, and Chungking, China, only 30 hours by air from New York City. Even faraway Brisbane, Australia, is but 35 hours distant. By the time this reaches the reader, they may be even closer in point of time, though not in actual distance. So rapid is the change in air transport that even *supersonic* speeds are reported to have been attained.

Planes also increase steadily in size. Exceeding other planes in operation, at least up to the present moment, is the Consolidated Vultee Clipper, which will carry 204 passengers and 15,300 pounds of baggage and mail. With air-conditioned cabin, it will operate at elevations up to 30,000 feet, where air resistance is low, with a cruising speed of 342 miles an hour and a cruising range of 4200 miles. Such developments indicate the probability that "flying box cars" will soon be bringing the products of distant lands, such as out-of-season fruits, to most of our urban centers.

Expansion of air transport has been so rapid that La Guardia Field, completed in March, 1940, is already inadequate and a new airport, the Jamaica Idlewild project, is to be constructed on Long Island at an estimated cost of $30,000,000 for runways alone. In all, there will be 12 of these, which will theoretically provide for 5760 landings and takeoffs each 24 hours.

Fig. 370. A jet-propelled fighter plane, the Lockheed P-80B.

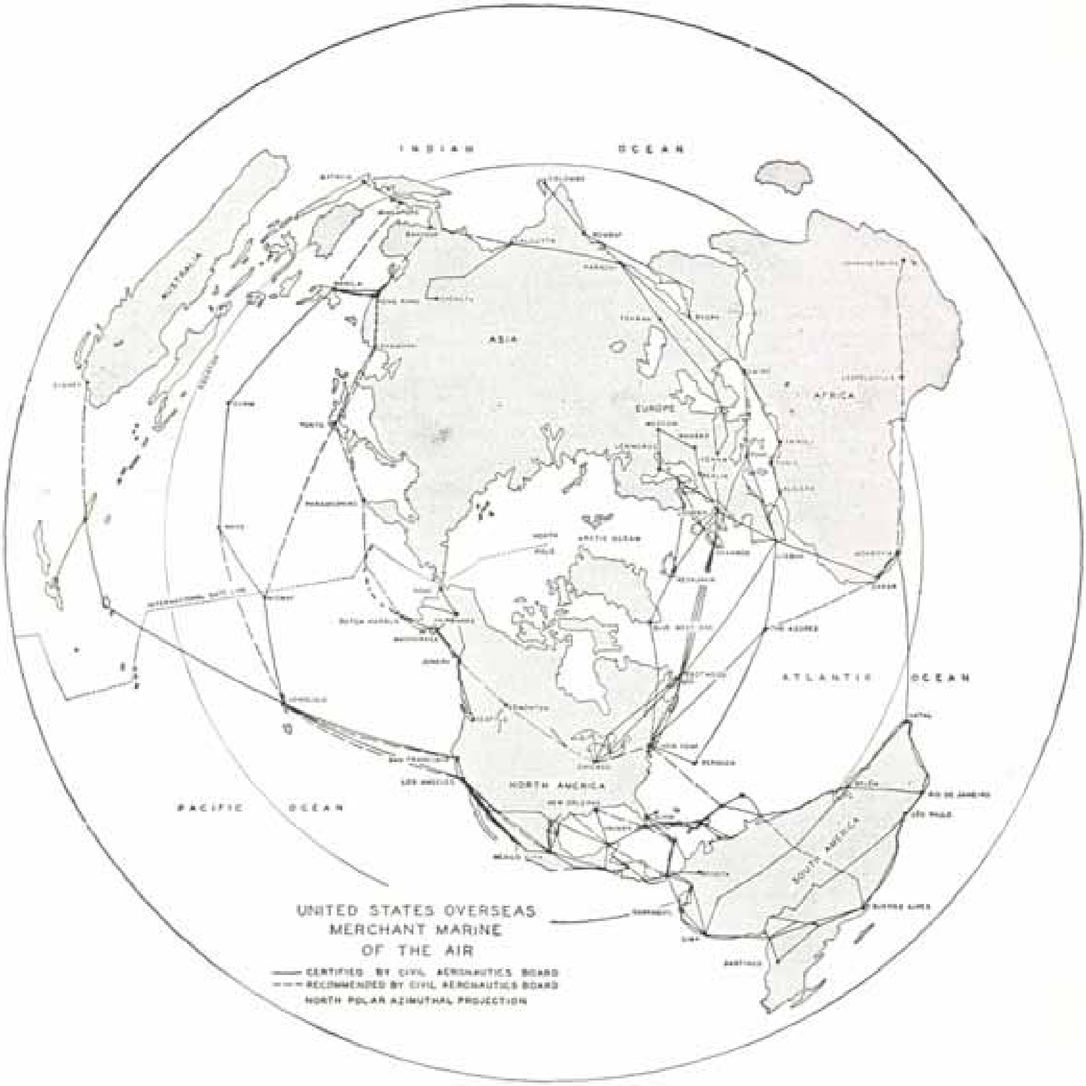

FIG. 371. Present and projected routes of the American "merchant marine of the air." There are no distant lands today, for aerial highways link the lands. (Base by courtesy of Air-Age Education Research.)

With increase of air travel, rates have decreased. At present, when all costs are included, it is not much more expensive to travel by air than by some other means; sometimes it is even cheaper. For example, the proposed rate from New York to London is $148, the time required, 13 hours and 40 minutes; from New York to Buenos Aires, $190.50, the time, 25 hours; from California to Hawaii, $96, the time 8 hours.

To operate airlines effectively over either land or water it is necessary to have advance information concerning the weather which will be encountered during flights. This information is likewise of great value for other purposes. This has led to a great increase of interest in weather forecasting during the past few years.

The development of improved means of transportation not only removes the protection formerly afforded by wide expanses of water in times of war, but it likewise introduces defense problems in times of peace, for disease and insect pests which were not serious problems in former

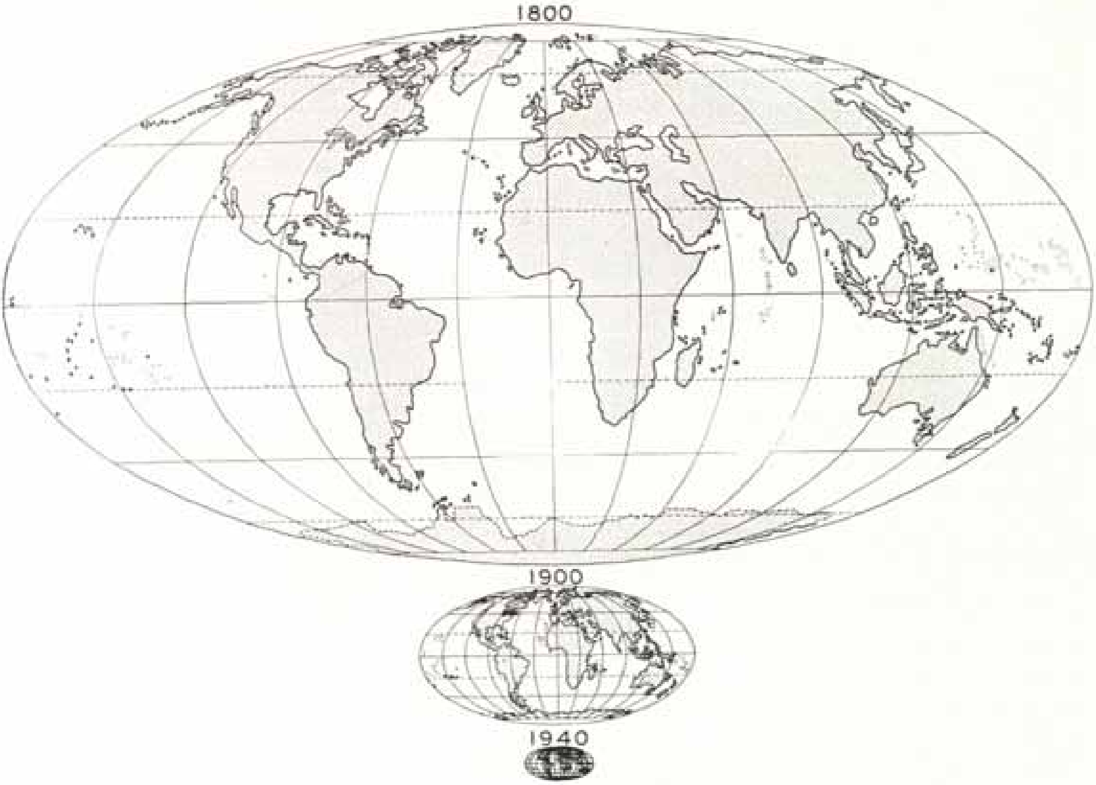

FIG. 372. A graphic representation of the shrinkage of the world with improvement of transportation during the past hundred years.

days now travel by air, and so rapidly that they threaten to take us unawares. The net result of air navigation, however, is beneficial, for any conquest of distance is to man's advantage, quite apart from the fact that new employment is afforded to workers.

Each new development in transportation has brought distant lands closer, lessened isolation, and increased the interdependence of the world's populations. For long, transportation was by land only and, in the earlier days, both slow and painful. Movement of goods was then difficult and expensive, and local self-sufficiency was the rule. Then man learned to navigate the oceans effectively, which soon increased his knowledge of the extent of the inhabited world and permitted trade in the products of distant areas, many previously unknown. At the same time, methods of moving goods by land improved with the building of railroads and the construction of hard-surfaced highways. This marked an important step forward, for it facilitated internal land communication and enabled assembling of goods at seaboard points for shipment across the oceans which connect the lands. Today, man not only moves by land and water, but he navigates the air as well, so that he is able to span the stretches of either land or water which separate him from his fellows in other parts of the world in a small fraction of the time required less than 25 years ago. These changes in methods of travel and transportation have opened up new possibilities and introduced new problems. The possibilities are those of travel to and of obtaining the products of many lands expeditiously; the problems are those arising from removal of the older isolation. These are problems both of times of peace and times of war. They confront us now and they press for immediate solution. If they are not met effectively, the results of this sudden change in the space relationships of the world's populations may well be disastrous.

QUESTIONS AND EXERCISES

1. What were some of the earliest supplemental devices employed by man to facilitate travel by land?
2. Report on the Mound Builders and the construction of the pyramids of Egypt. Where is man still a beast of burden? Why?
3. What animals has man pressed into his service to lighten his labors? Discuss the use and importance of each.
4. Which came first, the use of wheels or sleds? Where are sleds still used? Why?
5. Describe the evolution of the wheel and wheeled vehicles. Why are wheels of large diameter sometimes desirable? Where are carts with such wheels still used? Why? What effect did introduction of the wagon have on wheel sizes? Why?
6. Who were the first great road builders? Describe their roads and state their uses. Why are good roads important? What was the condition of European roads after the decline of Rome? What were the conditions of travel at that time?
7. Contrast early American roads and the conditions of travel at that time with those of the present.
8. When were canals first used? Where are they used extensively today? Why were they more successful at an earlier date than at present? Describe American canal construction.
9. State the early history of railroad development. Where did railroads originate? Trace the development of railroads and rail equipment in the United States.
10. How has development of other methods of transportation affected our rail lines? Is this advantageous? Why?
11. What development marks the third and latest important stage in the evolution of our present land-transportation system? When was the automobile introduced? Why is the automobile industry of the United States concentrated in the Middle West?
12. What effects has the automobile industry had on the area where it is concentrated? On the United States? On employment? On the railroads?
13. When did ocean navigation have its beginnings? Where? What were the early ships like? After what events did ocean navigation increase rapidly in importance? Why?
14. Describe shipping in the days of sail. Describe the evolution of the modern steamship. Why is ocean navigation so important?
15. What two types of craft are in use for navigation of the air? Which of the two is more important today? Trace its evolution.
16. Why does the trip from San Francisco to New York by stratoliner take less time than the one in the reverse direction?
17. Report on our "merchant marine of the air."
18. What problems has air navigation introduced? Are they important? Why?

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Chapter Thirty-Eight

COMMERCE AND INDUSTRY

The Development of Commerce. Commerce, or the exchange of goods on an extensive scale, is an economic activity of relatively recent development, for such trade involves both producers of important surpluses, the sellers, and desires which lead to acquisition of such surpluses by others, the buyers. Further, it necessitates the possibility of movement of commodities from the place of their origin to the markets where they are in demand. Neither of these basic requirements for the effective development of commerce existed during the earlier stages of man's development. In fact, it is only within the past one and one-half centuries that conditions have been favorable for the existence of large-scale trade as we know it today, and not everywhere even during that period. Thus commerce during the time when the known Western world was confined to areas around the Mediterranean, though important for that period, was small in amount by comparison with the present-day flow of trade.

So long as man was a nomadic hunter only and, even later, when pastoral pursuits or primitive agriculture afforded his support, his few wants were met, in either major part or completely from local resources. Even had they been more numerous, they could not have been adequately satisfied by exchange, for most of the time only a bare sufficiency of commodities and products to meet the most pressing needs was available and, when a rare surplus of these existed, it was never large. Such are the conditions which still exist in those parts of the world occupied by similar populations today. Hence the inhabitants of such areas supply but a negligible percentage of the goods handled in world trade. Further, even had surpluses been available among these earlier populations, the facilities for carrying on commerce were lacking so that no important trade could have resulted. Commerce, indeed, may be regarded either as a by-product of improved means of transportation or these means may be considered to have been developed as a stimulant to trade. Probably cause and effect have had reversed relationships in different cases.

The Basis for Commerce. The basis for commerce is the existence of surpluses and deficits. Therefore trade develops between areas with unlike types of production. Thus industrial areas may depend on those where agriculture is important for food; agricultural regions on others from which manufactures can be secured. Similarly, the peoples of the higher latitudes draw upon the tropics for those commodities they cannot produce or which they cannot produce to advantage; those of the tropics, upon intermediate latitudes for the products of the cooler parts of the earth. Again, trade will normally develop between areas with different types of industrial development. To institute important trade between areas with the same exportable surpluses is therefore difficult. This is one problem confronting us at the present moment in dealing with some of the countries of South America, one for which no satisfactory solution has been devised as yet.

In part at least, present surplus production is a result of increased specialization, today made possible by ability to satisfy accompanying deficits by import. For this reason, many formerly self-sufficient areas have become deficit regions in commodities they formerly produced locally. For example, where plantation agriculture invades the tropics, concentration on a single commercial crop often makes it necessary to import food for the workers, formerly supplied locally, but no longer available since their ener-

gies have been diverted to other types of productive activity. On many of these plantations, it is true, there is considerable supplementary agriculture. Thus, on the former Ford holdings in the Amazon basin, the attempt is made to meet local demands for food in part by cultivation of manioc, from which farina is made, and many vegetable crops. However, tropical plantations as a group must import foodstuffs.

Commerce is likewise affected by the cultures of populations, for these affect both desires and the possibility of satisfying them. Thus trade between the United States and China during earlier times was handicapped by the fact that we had little to offer which the Chinese desired, in exchange for the tea, silk, and other merchandise we wished to obtain. Even today, the trade between China and the balance of the world, though huge in total amount, is small when the enormous number of Chinese is considered. Hence, though the total foreign trade between China and other parts of the world had a total value of about $3,000,000,000 in 1926, when trade was undisturbed and normal, this was only slightly more than $6.00 per capita. Such a small amount per person results in part from cultural conditions in China.

Cultural Differences and Trade. The culture of a population group affects its needs and thus the demands imposed on commerce. Less advanced populations export raw materials and import manufactures; industrialized areas import food and export manufactures. These conditions influence the general nature of the present trade between China and the United States. In view of the fact that China is developing rapidly, we are told that there is a great opportunity to increase sales of machinery to the Chinese. However, such trade must be temporary only, for differences in culture disappear, and eventually China will become a competitor in the sale of manufactures. This has already occurred in Japan. Only a few years ago largely importers of factory equipment, in normal times the Japanese flood the markets of the world, including those of the United States, with fabricated products, made at such low costs that we find it difficult to meet the competition successfully.

Relation of Exports and Imports. Commerce involves an exchange of commodities. Therefore exports and imports must be equal in value for trade to be stable, or there must be a transfer on something of value of some other type to offset the difference. In trade with underdeveloped areas, this becomes very obvious, a decline in exports being accompanied, either immediately or very shortly thereafter, by a decrease in imports. Between more advanced populations, however, an excess of imports over exports in the trade between two countries may persist for many years, because of the more complex conditions surrounding the commercial relations of highly developed areas.

Transportation and Trade. Without effective means of transport, important commerce is impossible, for even though surpluses are available for exchange and deficits in these same commodities exist elsewhere, it is impossible to move them from the producing areas to those of potential consumption, except as transport is available. This is true as regards both internal exchange and commerce between distant regions.

Much, though not all internal trades, must be moved by overland routes. This makes good roads and an effective railway system desirable. Where these are lacking, exchange is handicapped. This is the case in China, where good roads are few and rail lines are nonexistent in many areas, particularly in the south and southwest. By contrast, western Europe and the United States have both good roads and rail lines and trade is highly developed. Complete dependence on interior waterways, either natural or artificial, is unsatisfactory, for though they may supplement other means of moving freight more or less effectively, they are inelastic and subject to other limitations as well. This is manifest in China, where waterways afford the most effective means for handling much of the freight traffic.

In trade between distant areas, either parts of the same or of different countries, or across the seas between the continents, the ocean is the great highway which carries most of the traffic. This is a comparatively recent development which has been considered in the preceding chapter. The efficiency of these routes has been greatly increased of late years by artificially linking the oceans by canals such as those which cut across the isthmuses of Suez and Panama. This has facilitated the flow of merchandise greatly by decreasing the length of haul necessary. Now, for example, it is no longer necessary

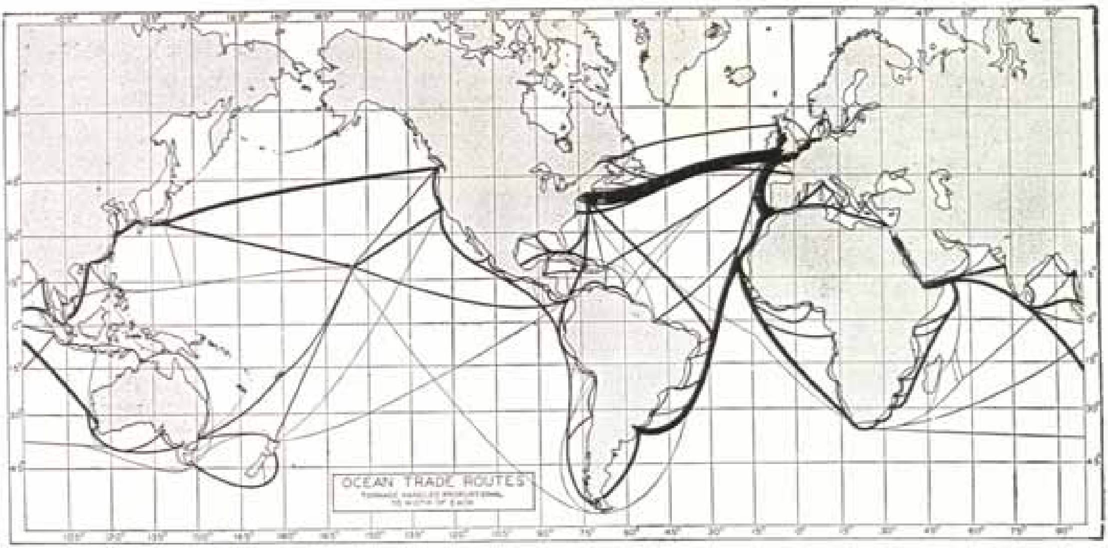


FIG. 373. Important trade routes of the world. The relative importance of these routes and the amount of freight they carry is indicated by the thickness of the lines.

for shipping from western Europe to round the Cape of Good Hope to reach southern and eastern Asia, and, similarly, the long and hazardous trip around Cape Horn may be avoided by use of the Panama Canal.

Trade Routes. The most important trade routes of the world are concentrated in intermediate latitudes because the necessities of their populations and the diversity of the products used are greater there than elsewhere. This is in part a result of natural conditions and partly because of the greater development of those parts of the earth's surface, with their Western industrial civilizations. The effect such development introduces is illustrated by the transformation which has occurred in Japan during the past half century. Earlier, a self-sufficient country supplying practically all her own needs, and with no important foreign trade, industrialization converted the Island Empire into one of the important commercial powers of the world, dependent for prosperity on the free exchange of goods with outside areas. It was, in fact, this need for the raw materials and markets of other countries which prompted the imperialistic ventures of Japan on the Asiatic mainland and elsewhere within recent years, with such disastrous results. This transformation produced a marked change in Japanese life and the outlook of the Japanese people within less than a human lifetime. Able to provide for her own needs and reluctant to open her doors to trade with others except under heavy restrictions less than a century ago, in fact refusing to do so until forced by the American navy, economic strangulation today confronts the country if commerce is cut off.

Not only are the great trade routes of the world concentrated in intermediate latitudes, except as they must cross the tropics to pass from hemisphere to hemisphere, but they are of maximum importance in the North Atlantic, between the highly developed areas of western Europe and eastern North America. Though of lesser importance elsewhere, their relative importance has increased greatly of late years in both the Pacific and Indian oceans, particularly in the former, accompanying recent development in southern and eastern Asia, where half of the present population of the world lives.

Changes of Trade Routes. Changes in the flow of trade result not only from increased development of areas such as those of eastern Asia, but as well from demands for new products and discovery of new sources of supply for others of longer use. Displacement of the earlier rubber supply of the Amazon basin by that of the East Indies, for example, caused a shift in freight movement. Similarly, discovery and exploitation of new supplies of a mineral like petroleum will produce equivalent change. In addition, inter-

ruption of normal trade, as by war, causes trade routes to alter.

Again, new and better means of transport often produce modification or even abandonment of older routes. Thus discovery and use of ocean highways have virtually eliminated use of many formerly important overland trade routes between Europe and Asia. Further, greater efficiency of ocean shipping has made longer travel without the necessity for frequent stops to take on coal a possibility and, though this has not always produced marked changes, it has made many minor alterations of the routes over which commerce moves. Perhaps the most significant changes which have occurred of late have resulted from recent developments in air navigation, for the merchant marine of the air can follow great-circle routes, undeterred by the interposition of land or masses of floating ice. Hence it may be that future air traffic will follow new paths in times to come, even over the frozen wastes of the Arctic and Antarctic, in an endeavor to shorten the length of flights, especially between parts of North America and western Europe, and probably eastern and southern Asia as well.

Furnishing employment to relatively few at the beginning of the nineteenth century, commerce today engages the time and energy of many. Some are employed in the production of equipment to move and the actual transport of commodities; others, in the building, maintenance, and operation of terminal facilities which have been developed to handle the continually growing volume of trade. Further, with increasing development almost everywhere, the number of persons employed increases appreciably year by year as new types of freight become available for shipment, and new demands afford additional markets for both products handled previously and others for which use has been discovered only recently. It is hazardous to prophesy, but the probability is good that we are only at the beginning of the era of exchange.

The Beginnings of Industrial Development. In very early times when his numbers were few and population was widely scattered, man was a "Jack of all trades," for he was forced by necessity to provide for all, or practically all, his wants without assistance from others. Soon, however, he began to live in groups of larger size, in which some individuals developed skills in the produc-

FIG. 374. The pottery at Pottertown, western Kentucky. The factory, workers, and the product, all of which is marketed by wagon within a few miles of the plant.

tion of certain articles which were in demand by all. Thus it may have been that one or more members of the group attained more than ordinary proficiency in fashioning arrowheads and stone tools; others developed the ability to make pottery better than any produced by their fellows. Simple as this production was, it may fairly be considered the rudimentary beginning of industry, as distinguished from hunting, fishing, pastoral pursuits, agriculture, and other economic activities. However, these were doubtless spare or at most only part-time occupations for many generations, since demand for the articles made was small within the limited areas where exchange was possible, and no methods for extending them were available, at that time.

Later, with expansion of the known world, discovery of new sources of supply and new kinds of raw materials, often better than any afforded locally, made available materials which could be used advantageously in the manufactures of that time. This expansion of the area within which trade could be transacted likewise made marketing of production possible on a scale hitherto unknown. In these earlier ventures in manufacture, man himself furnished the power needed, for utilization of the energy of falling water was unknown, and neither the steam engine nor other modern sources of power were available.

With increase in the volume of trade, as more and more distant lands were visited and their products were made available, specialization of occupation became ever more pronounced and the beginnings of present industrial development assumed recognizable form. This development was hastened by the use of water power and particularly accelerated by invention of the steam engine. However, though introduction of power alone made modern industrial development possible, it is still fair to consider industry the offspring of commerce, for until it was possible to assemble raw materials from many sources and market the production over equally extensive areas, all industry was perforce limited in both kind and volume.

Many of our great industrial plants of the present have developed from very unimposing beginnings. For example, according to R. M. Kier, the parent factory of the great American Optical Company of the present day at Southbridge, Massachusetts, was so small it was operated by the power supplied by a stream of such limited flow that it often dried up during the summer months, at which times a horse was used. Once, indeed, a Negro was employed at 10 cents an hour to take the place of the horse.

Though most of these smaller mills and factories have not developed into large-scale enterprises, and many have disappeared completely, enough have survived to illustrate the often small beginnings of many of our larger industrial plants of the present. In many parts of the world, however, as in China for example, most "factories" are still small enterprises using little power. Thus Chinese potteries may operate without its use, except as supplied by the foot of the potter who turns the table on which the clay to be fashioned rests. Similarly, lumber is often sawed by hand; macaroni is made in workshops; and many other products are manufactured in equally simple plants. In the less highly developed parts of the United States, there are likewise small-scale industries dependent entirely on local raw materials and local markets for sale of their production, much as in the days when all industry was carried on in similar plants, with limited numbers of workers.

Industry and Other Economic Activities. In the more densely populated and highly developed parts of the world, no single economic activity engages the energies of the inhabitants to the exclusion of all others, for development of any one affords opportunity for other forms of gainful employment. Industrialized areas are therefore not necessarily different from others, except that manufactures assume greater relative importance than elsewhere, to the extent that they are dominant. Even where this occurs, however, it is often true that other activities may be of great actual, even though locally of small relative importance.

Factors Affecting Localization of Industrial Development. Occasionally, one factor only may appear on superficial consideration to constitute the basis for the industrial development of a given area, though this must rarely if ever be true. For example, effective manufacture of lumber cannot develop except where forests grow, yet many forested areas have no important lumber manufacture. Similarly, iron ores alone will not ensure an iron and steel industry; clays, the manufacture of pottery; granite, an output of quarry products. In practice, therefore, not one,

FIG. 375. A Tampa cigar factory, where clear Havana cigars are made by hand. Here, the sex of the workers is immaterial, but they must be skilled; in other factories where machines are used, this is not fundamental. (Courtesy of the Tampa Chamber of Commerce.)

but ordinarily a combination of several favoring factors serves as the basis for industrial development of any importance. Though in the following consideration of the various factors which are important in contributing to the possibility of concentration of manufactures, each is discussed separately, it should be borne in mind that they do not in practice operate singly, but in combinations, and that, unless several are favorable the probability of extensive industrial development is ordinarily slight.

Human Choice and Industrial Development. Many of our present industries have developed from very small beginnings in locations determined by the place of residence of the individuals who started the enterprises. In their initial stages, they needed only limited amounts of power, relatively little raw material, few workers, and markets for the production were largely local. Such small ventures may continue to exist as small-scale enterprises for considerable periods of time in the absence of effective competition from without. Some, which later increase in size and enter outside markets with their products, may succeed, provided not too badly handicapped by factors not considered at the time the location of the plant was chosen; others fail when forced to meet more favored competitors in either wider markets or those of limited near-by areas. Even those which succeed may be handicapped, because not located more advantageously, but in sites chosen without due consideration of all the facts.

Raw Materials and Industrial Development. Industry draws on farms, quarries, mines, forests, and other sources for the raw materials which permit it to function. Access to such materials is therefore necessary and, the more readily accessible they are, the more favored is industry.

provided other conditions are satisfactory. Therefore milling tends to locate near sources of grain; packing plants where livestock is available; the lumber industry in forested areas; and others in comparable locations with reference to a supply of the materials used.

However, not all industries are affected to the same extent, for when the amount of raw material needed is small, its lack as a local resource may be relatively unimportant, for costs of transportation from distant sources may be negligible, and other favoring factors may more than offset the minor disadvantage of having to import. Thus the cotton textile industry is important in England, New England, and Japan, though no cotton is grown in any one of these areas. By contrast, when the volume of raw materials required is large, and their value per unit of weight is small, profitable industrial use is normally confined to those areas where they can be secured at low costs for transportation. This is true, for example, in the iron and steel industry, profitably developed in parts of our own country where raw materials are available, but supported only with government subsidy in Japan, where a satisfactory local supply of iron ore is lacking and the available coal is poor for use in blast furnaces. Further, it should be realized that other factors, as well as accessibility of raw materials, are important. These may include shipping qualities of raw materials and products, relative costs of transporting raw materials and finished production, power requirements, and others, for all play a part in localizing industrial development. Seldom, indeed, does consideration of one factor only lead to wise decision on any point. Certainly this is true with respect to locating an industrial plant.

Water Supply and Industrial Development. All types of industry use water, but needs as regards both quantity and quality vary greatly. For cooling only, it may be of any quality if not acid, but for use in steam boilers it should be free from both suspended and dissolved mineral matter. Where it is an ingredient of mixtures used in manufacturing processes, the quality required varies with the industry. For example, production of the finer grades of white paper necessitates use of a supply of better quality than is tolerable for making brown wrapping papers; in the manufacture of chemicals and drug products, it may even be necessary to use distilled water, since few natural waters are sufficiently pure.

Therefore, in locating new manufacturing plants, the character of the water supply should be considered, for an adequate volume is always necessary, and, though purification is possible, it adds to production costs. Early industrial development in the United States was confined almost entirely to areas which had good natural waters and, because of the importance of this factor, the direction of expansion since that date has been influenced by the nature of the water supply of the areas into which the various types of industry have spread.

Labor Supply and Industry. The location of many industries is related, at least in considerable part, to the presence of a satisfactory labor supply. Sometimes favorable conditions in this respect involve only an adequate reservoir of labor; again, there must be a supply of skilled labor. Often the sex of the workers is important; again, it is of no consequence, varying with the industry.

Thus certain industries may be widely diffused, insofar as labor supply affects their location. In the manufacture of cigars by machine, for example, power requirements are small, raw material can be shipped in at slight cost, and only an abundant supply of labor, at best but slightly skilled, is necessary. Therefore machine-made cigars are produced in numerous localities. The same is true for many other manufactures such as knit goods. By contrast, the manufacture of fine shoes and machine-shop products requires skilled workers. Therefore these industries are concentrated in more limited areas, where reservoirs of skilled labor are available.

This often tends to perpetuate certain industries in the areas of their origin, where accumulated capital adds advantage, even in the face of manifest handicaps such as lack of coal, easy access to necessary raw materials, and of nearness to consuming markets. This is, of course, always provided power requirements are not too large, the volume of raw materials needed is not too great, and the finished product is high in value but small in bulk. Industries of this type include those such as the manufacture of clocks, watches, firearms, fine machinery, fine textiles, and other products of similar character.

Other Factors and Industrial Development. Other factors which affect industrial development include climate, culture, capital and government. The fact that all highly industrialized

areas are located in intermediate latitudes is probably more than accidental, for the stimulating effects of certain climates is generally conceded, even though not all may agree with the more extreme views as to their influence.

The culture of a population group is likewise important. Thus, where long-established social practices tend to create preference for agriculture rather than mining or industry, the initiation of the latter may be difficult; on the other hand, where employment in factories is preferred to tilling the soil, industrial development is facilitated.

If a large-scale, factory type of industry is to develop, much capital is necessary, for such an organization of industry requires expenditures of large sums before either production or returns can be secured. Therefore poor areas are handicapped in starting industrial production, even where other conditions are favorable. This handicap will confront the Chinese if they attempt to develop industries based on natural advantages afforded by the country.

Again, the attitude of government is sometimes very important. Thus in Japan, where governmental encouragement, extending even to subsidies, was the rule in the past, industrial development was favored. By contrast, where punitive laws discouraging enterprise and initiative are enacted and enforced, or where government itself enters as a competitor, industry is hampered, sometimes to an extent that the competition of other areas cannot be met successfully. It is, of course, true that legislation alone cannot ensure industrial development, but only favor or prevent it. However, when government is hostile, and at the same time lacking in stability, capital is reluctant to venture, despite favoring natural conditions, and industrial development approaches zero, without much probability of any increase.

Transportation, Markets, and Industrial Development. Extensive industrial development cannot occur in the absence of an adequate transportation system, which is necessary for both the assembly of vital raw materials and the distribution of finished products. Such facilities are commonly lacking in sparsely populated areas. Further, important markets for manufactured products exist only where people live in considerable numbers. Hence industrial development tends to be concentrated in these same areas. Though it is true that all highly industrialized areas are densely populated, not all densely populated areas are characterized by a great development of factory industry, for this is limited to regions with Western types of economic activities.

The extensive industrial development of the present would have been impossible anywhere, even as short a time ago as the beginning of the previous century. At that time, therefore, all industrial plants were relatively small, production was limited, and markets were restricted, much as they are today in countries such as China. Only where the rail net is adequate, effective means of internal movement of goods by water may be available, highways are generally good, access to seaboard is assured, and markets are thereby accessible, is development of a high degree of industrialization possible even today. Thus western Europe, eastern United States, southern Japan, and limited areas elsewhere which enjoy these advantages, are the major centers of Western-type industrial development of the present.

The Iron and Steel Industry. This industry is basic in present Western industrial civilization, for it not only supplies the raw material used for fabrication of much of the equipment necessary in other economic activities and articles used in everyday life, but it produces as well the steels for making machine tools which permit production of the equipment of modern industrial plants. Therefore change and improvement in the manufacture of iron and steels, and in the fabrication of products from them, have far-reaching effects on all members of society.

During the past one and one-half decades, there has been greater improvement in steels than in any previous period of equal length, and at the same time prices have been lowered, with a temporary reversal of that trend of late. Today, steels are stronger, have better drawing properties, are more resistant to corrosion, and are usable at higher temperatures than in the past. These improvements have resulted from development of special types for different uses, each better in some of the particulars mentioned. The most dramatic change of the past few years has been the increased use of alloys, produced by the addition of small quantities of some other metal. Thus we have stainless steel which resists corrosion; nickel steel which is tough and ductile; tungsten steel from which tools that will retain

sharp cutting edges when red-hot are made; vanadium steel which has a fine grain; and several others. The most important of the substances added is manganese, used not only to produce a special steel, but as a deoxidizer and desulphurizer. In all, there are approximately 600 of these alloys, about 65 per cent of which are of great importance.

Not only have steels improved, but great progress has been made in production methods. Coke is now made largely in by-product rather than beehive ovens, which permits saving substances such as tar, crude light oil, ammonium sulphate, benzol, and toluol. Blast furnaces have almost doubled in size and increased in efficiency; steel mills have improved even more, with the electric furnace, which permits efficient control of high temperatures and oxygen supply, the latest development. Improvement, however, has been greatest in the rolling mills, where continuous rolling now permits performances hitherto impossible and at the same time reduces labor costs. Despite the preceding depression years, the capacity of the iron and steel industry of the United States was 65 per cent greater in 1940 than peak production during the First World War, and the industry employed 20 per cent more men than during 1930. Since 1940, there has been a comparable expansion of productive capacity, which should contribute substantially to the welfare of society.

Location of the Iron and Steel Industry. Manufacture of iron and steel, so fundamental in our type of civilization, affords an excellent example of the part several factors may play in influencing the location of a specific industry. In the case of the iron and steel industry, these are location of iron ore, coal, and markets for the production. The common statement that iron ore moves to coal to be smelted has a certain measure of truth, but if the attempt is made to explain the location of certain blast furnaces such as those of the Chicago area on that basis, it becomes apparent that it is at best only a half-truth. It probably arises from the fact that, though it requires only ½ to 1½ tons of coke to smelt a ton of iron ore, variable with the ore, conversion of pig iron to steel requires use of more coal, so that the total consumption of coal to convert the ore to steel frequently makes it advantageous to smelt the ore in or near the coal fields, where the market for pig iron exists. In the final analysis, however, location of the market for the pig iron, for the steel made from it, and for fabricated steel products, has an important effect on the distribution of the iron and steel industry. The fact that three factors in all enter to influence the exact location of the industry introduces several possibilities, variable with the relative location of the iron ore, the coking coals, and the markets for the pig iron, steel, and fabricated products. If all occur together, the best location for the industry is obvious; if they are separated, the exact location of the industry will vary with the particular combination of conditions. But markets will always be important. Therefore iron ore will not always move to coal; sometimes, as in the Chicago area, both move to the market.

The Major Industrial Areas of Europe. These are located in one of the world's three great concentrations of population. This affords an abundant labor supply, as well as one highly skilled, and an important local market for the production, in both the industrialized area and in near-by predominantly agricultural regions. Further, natural conditions and certain aspects of the cultural environment favor industrial development in this part of the world.

Both iron ores and coal suitable for smelting them are present on the continent in western Europe, in Great Britain, and to the north of the Black Sea in the U.S.S.R. A highly developed transportation system, both rail and waterway, permits assembly of the raw materials necessary as the basis for the heavy industries and distribution of their production. Sometimes, indeed, the producing areas of western Europe are at seaboard so that ores from Spain and Sweden may be obtained by cheap water transport, to supplement local supplies if necessary; and production can be marketed to advantage in similar fashion. Even though not at seaboard, the highly developed system of interior waterways links many inland points with ocean transport so effectively that the interior location is no great handicap. In the Soviet Union, where present industrial development is somewhat less important, the heavy industries are made possible by smelting the iron ore of the Krivoi Rog district by use of coal from the Donets basin.

An abundance of coal affords the possibility for development of power, and the products of the blast furnaces and steel mills supply raw material and thus opportunity for other types of

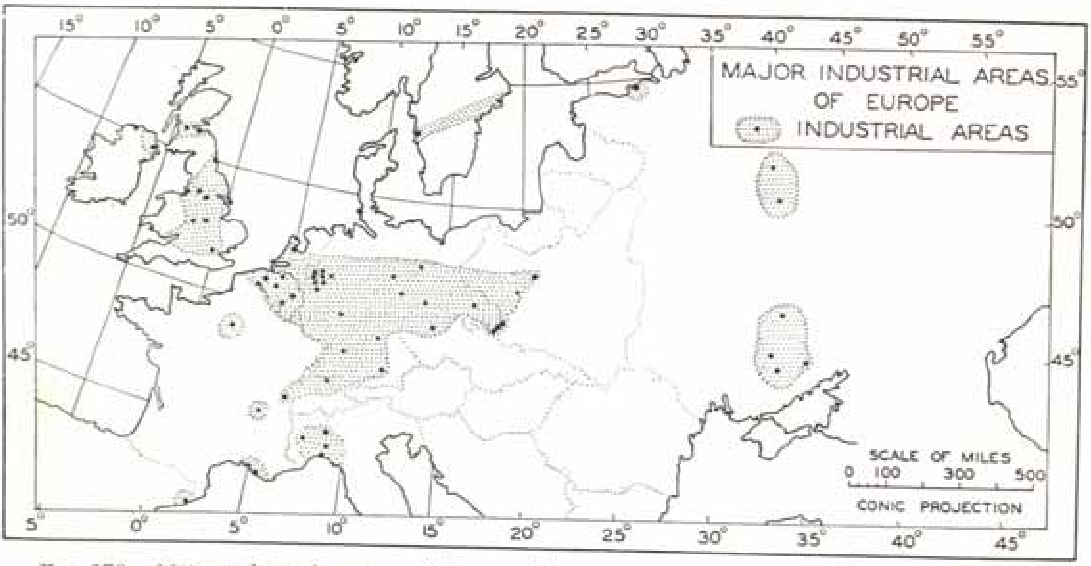


FIG. 376. Major industrial regions of Europe. This map is drawn on the assumption that geographical conditions rather than political considerations will, over any extended period of time, determine the localization of industry.

manufacture. Extensive development of industry means employment for many, both in cities and on farms, where intensive types of agriculture are profitable because of the demands of near-by urban markets for the yields of these types of production. Further, these industrialized areas are adequately served, not only by a network of waterways and rail lines, but by good roads as well. In addition, they have adequate facilities for overseas shipments of exports to

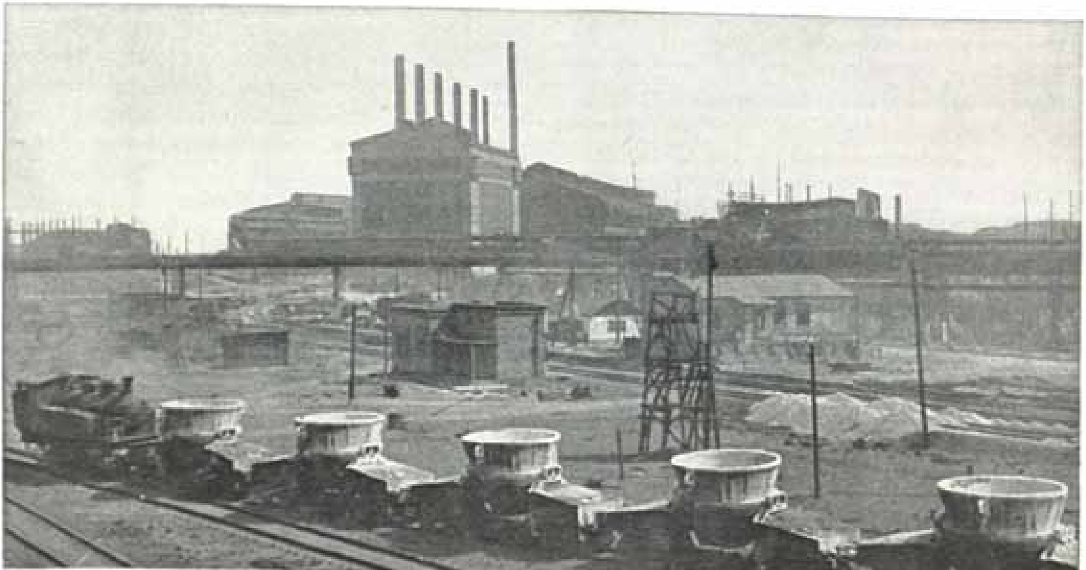


FIG. 377. Iron from the blast furnaces on its way to the steel mill at Zaporozhe, a steel-manufacturing center of the U.S.S.R., on the Dnieper River, where the Krivoi Rog iron ore is smelted by use of coal from the Donets Basin. (Courtesy of Sovfoto.)

other lands. Because of the many favoring factors, these industrialized areas are the home of both dense and advanced populations.

Though the prewar pattern of industrial development in Europe has been disturbed by the war and subsequent regulation of enterprise, the changes produced have not altered the general location of production. Moreover, it is highly probable that much of the change now contemplated may be abandoned rather soon. Though it is possible, of course, to regulate production by administrative edict, such regulation, except as made necessary as a means of protection from aggression, is manifestly undesirable, for it interferes with use of opportunity offered by environment and has many manifest disadvantages. Therefore it is to be hoped that it will be necessary to impose arbitrary restrictions on industry for only a limited period of time.

The Industrial Regions of the Orient. There are several widely dispersed industrialized areas in Asia, but that of Japan is the most important at present. The Japanese center extends from northern Kyushu, the southern island, up the coast of the main island, Honshu, to slightly north of Tokyo. In this relatively short and very attenuated area are concentrated most of the industrial plants of importance in Japan, all handicapped to some extent by a late start, but likewise benefiting from being able to profit from the experience of others and thus to avoid many losses incident to the experimental stages of industry elsewhere. The heavy industries are in the south, in northern Kyushu. Here are located

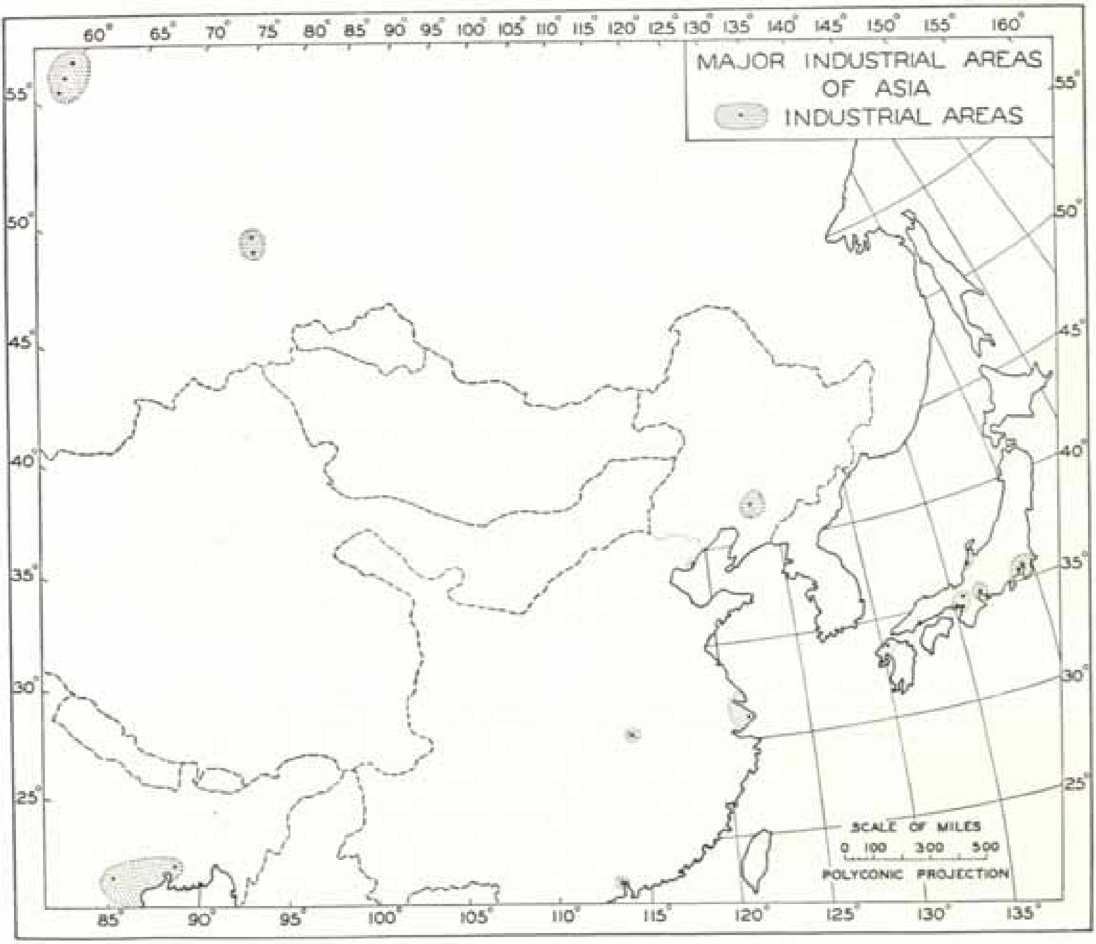


FIG. 378. The major industrial areas of Asia.

the great Yawata iron and steel works which smelt a large fraction of the iron ore and make most of the steel produced in Japan, using imported ore and some imported coal. Farther north, in the Osaka area, are the largest textile mills in Japan, and plants for the fabrication of steel products. Still farther north, in and around Tokyo, production is more diversified. To a considerable extent, Japanese industrial development is without a substantial basis, for the iron and steel industry lacks locally available supplies of essential raw materials and therefore its existence is possible only with government operation and subsidy. Only the textile industries, the most important of all, enjoy any marked advantages and, even for them, most of the raw material used must be imported. Other industrial plants such as paper mills, potteries, breweries, and service enterprises are of secondary importance only, and most factories, except textile mills, iron and steel plants, and a few others such as shipyards, are small and employ relatively few workers. The war and subsequent regulation will have little or no effect on the location of Japanese industry, but may alter its character materially, principally by elimination of most of the heavy industries.

In both China and India, industrial development is in its infancy and confined to restricted areas. In India, the iron and steel industry has attained considerable importance in the Calcutta area, where the Tata Iron and Steel Works, representing an investment of $100,000,000, are reputed to be the largest single plant in the British Empire, as well as a very low cost producer of pig iron from near-by deposits of iron ore. As in Japan, however, the textile mills in the Bombay and Calcutta areas are the most important of the industrial plants of India at the present time.

In China, important present industrial development is limited to the coastal regions, with the textile industries dominant. This is a logical development, for climate permits growth of cotton and this, in combination with the huge local market, affords a substantial basis for the industry. In the future, however, it is possible that the heavy industries, already of considerable importance in Manchuria, will assume greater relative importance, for China has enormous reserves of high-grade coal which have been virtually untouched as yet.

Other industrialized Asiatic areas of great potential promise are those of the U.S.S.R., in Siberia, a development of recent years. The Soviet Union probably ranks second only to the United States in the variety and value of its mineral resources, and these are now being developed rapidly to serve as the basis for industry. Already there is important steel production at Stalinsk, formerly known as Kuznets, where the furnaces have a capacity equal to those of Magnitogorsk, nearly 1500 miles to the west. New mills are also in operation on the lower Amur and at Tashkent, with still others planned for future construction. These developments are part of a planned movement to shift vital centers of production to the Urals and their east where they will be more centrally located and less vulnerable to attack. One of the results of the war has been to speed up this shift, which will have far-reaching effects on the economy of the Siberian possessions of the U.S.S.R.

Industrial Regions of the United States. Urbanization always leads to development of certain service industries, such as bakeries, and frequently to that of some of slightly different character, such as assembly plants. However, the more important basic industries tend to concentrate in limited areas of greater advantage. Therefore many urban centers are of commercial rather than industrial importance. Thus, in the United States, the most important of the industrialized areas are all east of the Mississippi River and, with a few exceptions, the most notable of which is the Birmingham district, north of the 38th parallel of latitude. This has resulted from the disposition of natural resources, particularly of iron ores and coal; transportation facilities, including those of our inland seas, the Great Lakes; and the agricultural desirability of this part of the United States, with its population of high per capita purchasing power. This affords local markets for industrial production, in addition to that made available in faraway areas by contact with the sea. Still other factors such as the course of settlement and the Civil War have also played a part in localizing industrial development in the United States.

Not all parts of this vast area are alike as regards type of industrial development. Some, in southeastern Pennsylvania, the Pittsburgh district, and around Gary and South Chicago, are characterized by heavy industries; others in the vicinity of Buffalo, by chemical plants; still others, in the Detroit area and west of Lake

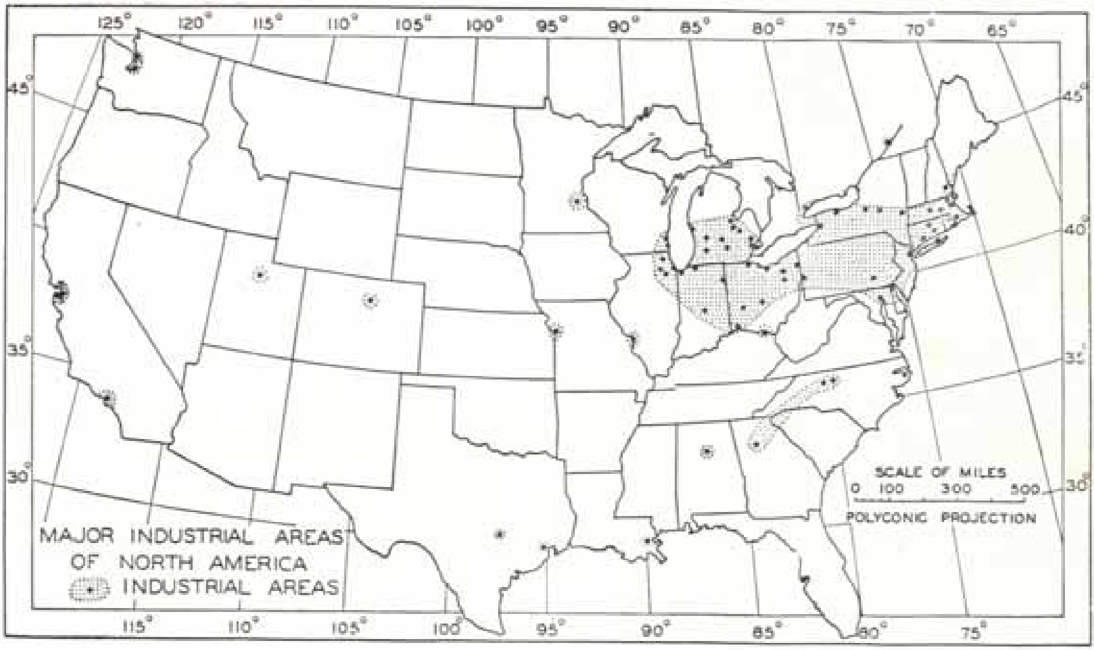


FIG. 379. The major industrial areas of the United States.

Michigan, by automobile factories and others fabricating steel products. In southern and southeastern New England, by contrast, light industries such as textile mills, shoe factories, machine shops for making fine machinery, and others of similar character are typical. In still other districts, as around New York City and along the route of the New York State Barge Canal, the manufacture of shirts, collars, and clothing assumes importance and, in certain limited areas farther west, furniture, dairy, and other miscellaneous products become characteristic. Where these lighter industries develop, it is often true that the favorable factors which influence their location are the presence of a reservoir of labor and nearness to markets rather than accessibility of raw materials.

Southern New England, an Industrial Area. Southern New England is a land of cities and villages, for nearly 84 per cent of the total population of Connecticut, Rhode Island, Massachusetts, and southeastern New Hampshire live in incorporated places of 2500 or more inhabitants, and an additional 13 per cent in smaller communities. In Rhode Island, where this distribution is most pronounced, less than 1.5 per cent of the population live on farms. This has not always been so, for the early colonists attempted to wrest a living from the soil. Soon, however, they realized that this would be difficult, for soils are frequently thin, poor, and stony, except in a few favored localities; slopes are often steep; and climate restricts the number of crops which can be grown profitably.

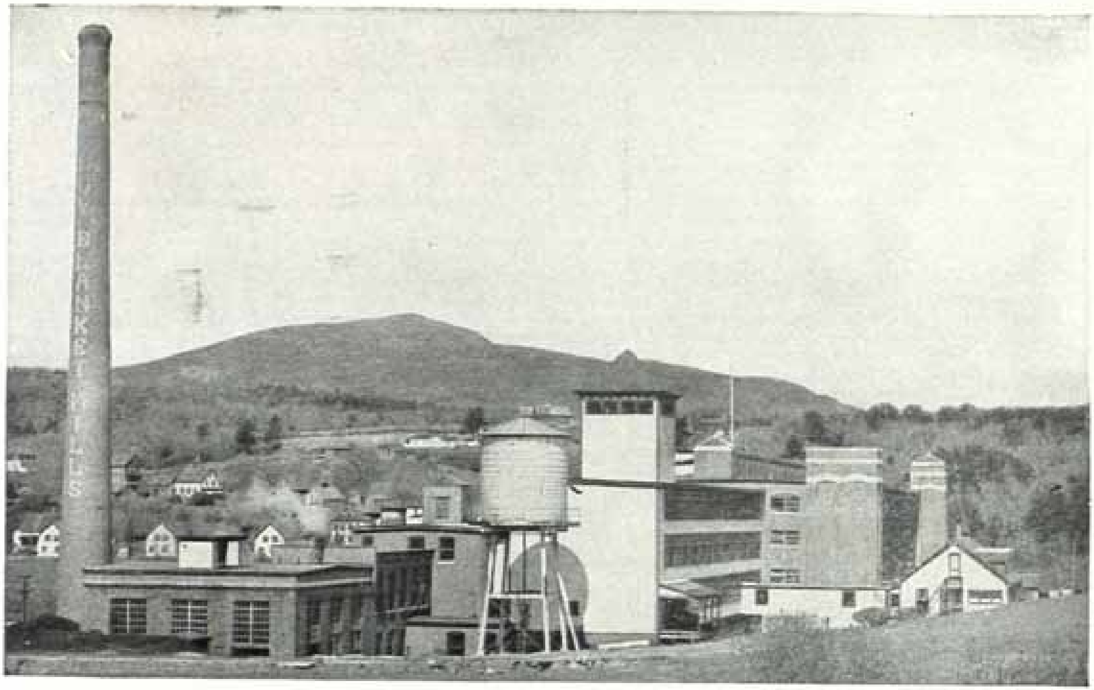
When the early settlers looked toward the sea, however, they saw opportunity for fishing; numerous harbors afforded shelter for fishing craft; and forests furnished the material for their construction. Therefore shipbuilding early assumed importance, to be followed by trade in fish and forest products in exchange for those of the other colonies and of areas across the seas. This led to assembly of raw materials of types suitable for manufacture. Then power possibilities resulting from glaciation tempted building of small factories which were the beginnings of the industrial enterprises of the present, and their associated trade. This advantage of an early start has been an important factor in the present industrial development of New England, for movement of a plant once it is located is accompanied by difficulties and not common in the absence of an extremely compelling reason. Further, in areas where certain types of manufacture have been

FIG. 380. Manitowoc plant of the Whitehouse Milk Company, Manitowoc, Wisconsin. In the dairy region of southern Wisconsin there are not only many plants such as the one shown above, which produces milk products, but others as well which manufacture the equipment and machinery used in the dairy industry. (Courtesy of the Manitowoc Chamber of Commerce.)

established for long periods of time, workers for these same plants, or for new enterprises producing the same types of goods, are easy to secure from the reservoir of trained labor which accumulates under such conditions. It is doubtless true that, if sites for certain New England industries were to be selected today, without taking into account the advantages which have accrued from an early start, other locations would be chosen for them.

The Civil War worked a revolution in the economic life of New England. The people turned from the sea to the land for support, even though it still refused any great opportunity, except where industrial development was possible, but that possibility was widespread, for small power sites were numerous, and coal could be obtained from relatively near-by areas. Further, blankets, uniforms, firearms, ammunition, and other manufactures were in great demand during this period, for even then equipment was necessary to win battles. Whether the right was on the side of the North may be a matter of opinion, but it is certainly true that the factories were, and sale of their products brought a flow of money to New England towns. This development of industry tempted movement from farm to city, where a better living could be secured with less effort than on many of New England's agriculturally unpromising hillsides, which had to compete with the better lands of the interior. This was the beginning of a movement which, with brief interruptions, has been in progress ever since. Later, these industries were protected by tariff walls which assured a large share of American markets to New England producers. Of late, it is true, some of the mill towns are far from prosperous, for many plants have shifted south to take advantage of more favorable labor conditions and legislation.

Typical production of the New England industries is of small bulk but high value, articles in which the cost of raw materials is relatively small, but the value added by manufacture is considerable. This must be so because raw materials used are largely imported, and even the coal used to generate much of the power must be moved for some distance. Further, many of the markets for the products of the factories are distant. Therefore what the New England manufacturer sells is the product of skilled labor, and the price he secures in larger part represents the wages of labor, plus a return to management, and interest on the capital invested.



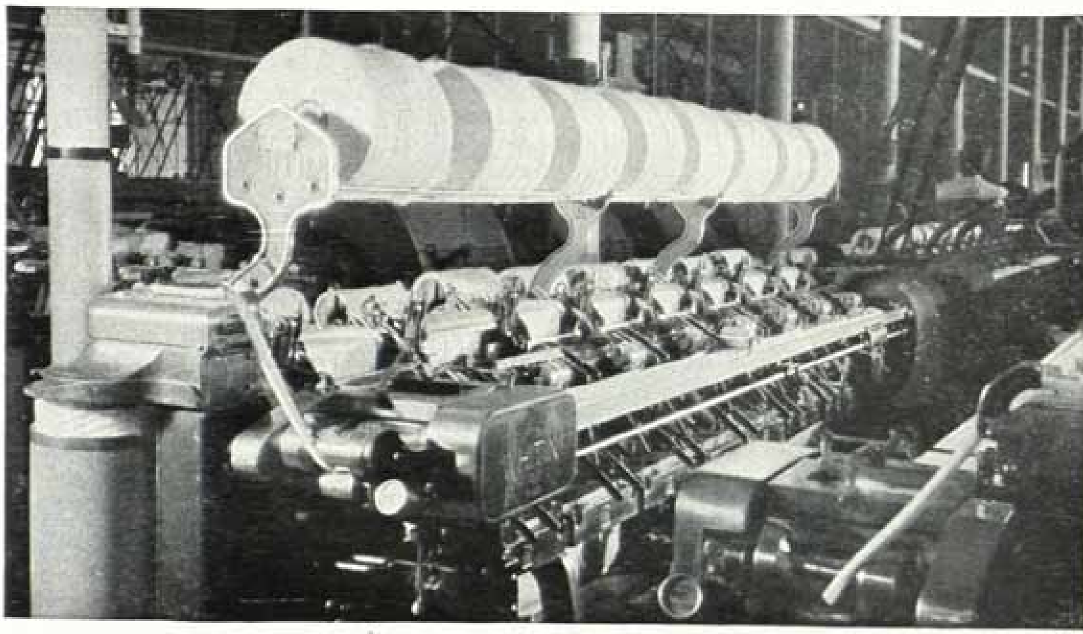


Fig. 381. *Top:* Blanket mill at Troy, New Hampshire. (Courtesy of the Monadnock Region Association.) *Bottom:* Interior of a modern Massachusetts mill which specializes in the manufacture of fine textiles. In this industry, extensive use of machinery and skilled labor, and the high value of the product offset the disadvantages of lack of a local supply of raw material and distant markets. (Courtesy of the Massachusetts Development and Industrial Commission.)

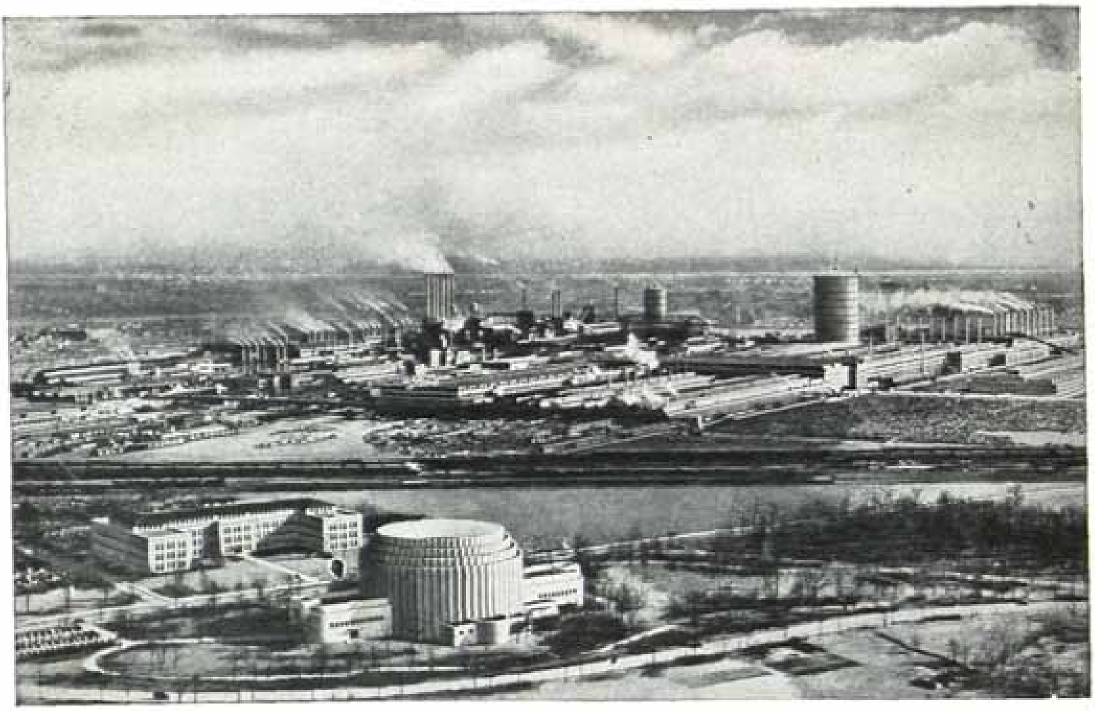


FIG. 382. *Top:* The Rouge Plant of the Ford Motor Company, located on the Rouge a short distance above where it flows into the Detroit River, which shows in the background. This location makes it possible to bring in lumber, iron ore, limestone, coal, and other raw material by water for discharge at the docks adjoining the blast furnaces and elsewhere, for the Rouge penetrates to the heart of the site. This plant, which employs 86,000 men, is the largest integrated, privately owned, industrial enterprise in the world. Covering nearly 2 square miles, it includes coke ovens, blast furnaces, open-hearth furnaces, an electric furnace, rolling mills, forging shops, tool and die shops, and other units for the fabrication of steel products. In addition, there is a cement mill, a tire factory, a paper mill, a box factory, a glass manufacturing plant, and others, plus 14 miles of roads and 92 miles of railroad to serve all. Indicating the importance of water supply in industry, this plant uses as much water as would a city of more than 2,000,000 inhabitants. In the center of the view above are the coke ovens; to their left, the blast furnaces; beyond them are the tall stacks of the power house, the largest private power plant in the world. To the right of the large gas storage tank are the open-hearth furnaces. Included among the other buildings are assembly plants and even a hospital and a trade school. The rotunda and office building are in the foreground; at the extreme right are some of the parked automobiles of the workers.

Bottom: A blast furnace at the River Rouge Plant of the Ford Motor Company. The cars are designed to carry molten iron from the blast furnaces to other parts of the plant. (Courtesy of the Ford Motor Company.)

Boston, with a population of 769,520 in 1940, is the hub of industrial New England. Within a radius of less than 30 miles, in what may be termed the Boston "agglomeration," live nearly 2,500,000 people, more than 25 per cent of all in New England, many in communities with coalescing limits. In this area, which produces one-third of the nation's shoes, the leather goods and shoe-making industries dominate, though there are also many others, for this is a region of diversified production. Surrounding this core area, and extending from Lowell and Lawrence on the Lower Merrimac to Fall River, Massachusetts, is a belt in which the manufacture of textiles, both cotton and wool, assumes great importance. This industry, securing an early start because of sources of power, a favorable climate, and the existence of capital willing to venture, was protected later by the initial investment and high tariffs. Possibly, too, as Huntington suggests, the stimulating character of the New England climate may have contributed to the perpetuation of this and other industries in the areas of their origin. Of late, however, with dwindling immigration, growth of labor unions, and new social legislation, some of the former advantages have been largely offset and migration to the South has occurred, to profit from both less repressive legislation and more favorable labor conditions. Still farther to the west and southwest of Boston, extending south from Springfield, Massachusetts, machine shops, brass, and hardware manufacturers replace those nearer the Boston center. Products include watches, clocks, tools, firearms, needles, pins, and similar articles. There is a curious grouping of economic activities in this belt, for not only does it supply firearms, but Hartford is the location of headquarters for many of the large insurance companies.

Zonal Arrangement of Industries Elsewhere. This zoning of industries is not confined to New England, for a similar arrangement may be observed in many other areas, including southern Michigan. There, in Detroit itself, the manufacture of complete automobiles is most important; in the peripheral portions of the hub area, auto-

FIG. 383. Final assembly line of the Ford Motor Company. As cars travel down the line past the workmen, each performs a few simple operations, or adds one or more parts, until the finished car rolls off as shown above. Such methods of production make American factories lead all others in the cheapness of their products, despite the high wages paid. (Ford News Bureau Photo.)

mobile parts are of greater relative importance. Then, surrounding this central portion, is a belt of diversified manufactures including chemicals, furniture, paper, and other products. Beyond, on the margin toward Chicago, where the products of the blast furnaces and steel mills of Gary and South Chicago are readily available, fabrication of iron and steel products assumes importance. This zoning is likewise in considerable part a by-product of the presence of labor trained in certain pursuits.

Postwar Industrial Areas in the United States. During the war there was a marked dispersal of industry, and several new centers developed under the stimulus of a necessity which did not count costs. Whether these new centers will survive in the face of postwar competition will depend to a large extent on governmental policies which cannot be forecast. Some of them will certainly cease to function in an important way; others, with some support, may continue in production if the plants, constructed at excessive costs, are sold at prices which will permit their continued operation.

The Future of Industrial Development. The extensive industrialization of the present is a development of the past half century, for mass production was unknown in 1890, and only in its infancy for a number of years thereafter. This was because the complicated machine tools which have made it a possibility were not perfected until rather recently. Up to the present, this change in the character of our civilization has been accompanied by a rapid drift of population from the farms to the cities and great increase in the size of urban centers. Whether this will continue is debatable, but it affords an interesting field for speculation, especially so in view of the fact that many cities lost population between 1930 and 1940. It is almost certain, however, that whatever the distribution of population between farm and city may be in the future, we are only at the beginning of great discoveries which will free man from necessity for long hours of toil. There have already been great changes on the farms in this direction. The cradle and the flail have been displaced by the harvesting machine, in its extreme development, the combine; the farmer now rides when he plows and often uses a tractor rather than horses; he may even do his milking with a machine. This has decreased the labor requirement for growing crops so that we now produce more with fewer farms and farmers. The farmer's wife profits in a similar way, though to a lesser degree, from the use of laborsaving devices.

It may be true that the agricultural frontier has disappeared, but this never offered great economic opportunity, whereas that of the present, the technical and industrial frontier, does. Thus, if man uses opportunity wisely, the future should hold much in store. We have always had with us the prophets of despair, those who view the future only with gloom, but their prophecies have always been discredited in the past. Certainly, if the teachings of experience have value, they indicate a similar fate for the preachments of those who today believe that we have nothing left except the possibility of dividing our present possessions and being content.

QUESTIONS AND EXERCISES

1. Why is important commerce of relatively recent development?
2. What is the basis for commerce? What is the relation between specialization of production and commerce?
3. How do cultural differences of populations affect trade between them? Illustrate by the trade of China and Japan.
4. How does transportation affect commerce? Illustrate by examples.
5. Where are the great trade routes of the world located? Why? How has the development of trade affected Japan?
6. What factors will cause alteration of trade routes? Cite examples of changes produced by these factors. To what extent does commerce afford employment today? What is the probable future of commerce?
7. Trace the evolution of industrial development. Where is small-scale industry still important? Why?
8. State the factors which affect localization of industrial development. How does human choice function? Illustrate by examples.
9. How does ease of access to raw materials function in localizing industrial development? Is this factor of equal importance in all industries? Why so important in the heavy industries?
10. Why is a satisfactory water supply necessary in industry? Is the quality of the water supply

equally important in all industries? Why? How has water supply affected the localization of industry in the United States?

11. How does labor supply affect the localization of industry? Does it affect all industries in exactly the same manner? Illustrate by examples, including some of the New England industries.
12. Discuss the importance of climate, culture, capital, and government in their effect on industrial development.
13. How has government functioned in Japan to promote industrial development? Why have these steps been taken to encourage industry? State some areas where government has operated in different fashion and explain why.
14. What effect do transportation and markets have on the location of industrialized areas?
15. Discuss the factors which influence the location of the iron and steel industry. Which affect the industry as developed in the Chicago-Gary area?
16. Locate the industrial areas of Europe. What is the basis for the development of industry in those areas? What changes have been produced by the war? Will these probably be permanent? Why?
17. Where is industrial development concentrated in the United States? Why? What are the characteristic types of industry which develop elsewhere? How has the war affected the distribution of industry in the United States? Will these changes probably be permanent? Why?
18. Locate the most important industrialized areas of the Orient and explain the basis for the development in each. How do the industries of Japan vary from south to north? Why?
19. To what extent are China and India industrialized? What is the character of the present industrial development in these countries? What is the probable future of industrial development in China and India?
20. Discuss the industrial development of Siberia. Why has development there been very rapid of late years? Why is this development of great importance?
21. Trace the evolution of New England industrial development and discuss its character and zoning. Why are certain types of industry migrating from New England to the South?
22. Discuss the probable future development and location of industrialized areas.
23. What have been some of the effects of industrial development, especially on standards of living? What does the future probably hold for industry and its effects?

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Smith, J. R., and Phillips, M. O., *North America*, Harcourt-Brace and Company, Inc., New York, 1940, pp. 83–109.

This reference supplies a description of the development of industry and the present industrial development of New England. These topics are discussed at much greater length than in your text, and in an interesting manner.

Chapter Thirty-Nine

CITIES AND URBANIZATION

The Beginnings of Urban Development. Cities are functional, not accidental developments, for they appear only where they perform useful services, and they grow only in response to demands of their tributary areas. Therefore in sparsely populated regions with poor means of communication, where both the areas to be served and the needs to be satisfied are limited, they are few in number and generally small. In highly developed, densely populated regions, by contrast, they are more numerous, often closely spaced, and sometimes of great size, because the demands on them for the services they render are much more extensive.

Among primitive populations, indeed, where each individual leads a more or less self-sufficient type of existence, urban centers as we know them cannot properly be said to exist. Instead, their equivalent may be no more than a cluster of huts, located on highways it is true, but organized primarily for neither trade nor manufacture, but largely for protection. Such settlements among both hunting and pastoral populations often possess little permanence, though occasionally some such villages, occupied for at least part of the year, may maintain fixed locations. In general, however, initiation of what may properly be considered the beginnings of urban aggregations, from some of which have evolved our present-day larger cities, is deferred until sedentary occupancy has become well established.

Location of Cities. Cities are always located at a focus of highways. This may be: (1) where roads converge at a stream crossing, a mountain pass, the head of a large lake, or of navigation on a river; (2) at a junction of river highways or at the mouth of a stream, where coastwise and river-borne trade meet at a common point; (3) at a convergence of important routes where harbor facilities are adequate to accommodate ocean-borne commerce and the site permits building a city; and (4) at a focus of important rail routes. Such locations afford ease of access to raw materials and markets and commonly to sources of power as well. They are likewise transhipment centers, where bulk breakage occurs, that is, where freight arriving in bulk is divided into smaller lots for distribution. Not all these types of location are equally favored nor have all functioned in exactly the same degree at different times. Further, the larger cities commonly combine the advantages of several, the number varying from time to time in the history of a given city. Thus New York, originally having advantages of access to the interior by river, supplemented later by canal, and ease of communication by sea, today profits from rail lines which tie it to the interior west of the Appalachians. Similarly, St. Louis, always a focus of river highways, today possesses the advantage of converging railroads.

In early times, rivers were commonly crossed at fords or shallows, in the absence of bridges. Often, therefore, roads converged from several directions on such places if the river was deep and favorable crossings were few in number. Thus the Roman roads focused on the present site of London, at the ford nearest the mouth of the Thames. That such sites afford possibilities for urban development is indicated by the fact that several English cities contain "Stratford" in their names, because the road or street crossed the river at that location by a ford. Similarly, roads tend to converge near passes, to take advantage of such breaks or low spots in mountain barriers. Thus roads focus on the site of Pittsburgh, Pennsylvania. Again, roads converge at the end of a large lake used for transportation and at the head

of navigation on a river. Such are the locations of Chicago and St. Paul respectively, the former at the end of Lake Michigan, the latter at the head of natural navigation on the Mississippi River.

During that long period when much or most inland trade moved by water, in the absence of effective means of transport by land, sites on river highways were favored locations for urban development and, doubly so, when at or near the confluence of several rivers of some size which were used extensively. St. Louis has this type of location, and so long as inland waters were the principal highways of both travel and transport this city maintained supremacy among the urban aggregations of the middle and upper Mississippi Valley as a result of this natural advantage.

A focus of ocean routes also affords a favored location for city growth, since it permits assembly of merchandise to advantage, not only from along the coast but from overseas as well, by use of cheap water transportation. Therefore many seaports have grown to be great cities. This type of location becomes even more desirable if it is at or near the mouth of a large river which offers access to the interior, for this focuses not only coastwise and other sea trade, but river-borne traffic as well, on a single location. New Orleans on the Gulf Coast; Portland on the lower Willamette; and Shanghai at the seaboard end of the Yangtze, the great east-west highway of central China, all profit from this type of location. Such a seaboard location was a particularly important advantage during the period subsequent to the development of ocean transport, but prior to that of railroads. Moreover, it still preserves its significance, not only without decrease but rather with increase of importance, even though other forms of transport now make city development a reality where it was formerly an impossibility. For long,

FIG. 384. A view of Portland, Oregon, a great city and port at the junction of the Willamette and Columbia rivers, 100 miles from the sea, with which connection is afforded by a channel of sufficient depth to accommodate ocean shipping. In the background is Mt. Hood. Connected with the interior by rail lines and by the Columbia River, navigable into eastern Washington and being improved steadily, this location affords a logical outlet for the products of the interior, with effective handling of these commodities assured by 27 miles of deep-water frontage and modern equipment for loading and unloading freight. (Courtesy of the Portland Chamber of Commerce.)

indeed, essentially all the great cities of the world were seaports, and this is still true for many such as London, New York, Tokyo, Buenos Aires, and Sydney, each the largest city for the continent in or near which it is located.

Since development of effective land transport, particularly by rail, inland sites have taken on advantages of location not previously possessed. Thus Indianapolis profits from the fact it is located where railroads converge, and the same is true for other cities such as Chicago, which likewise have other locational advantages.

It will be noted that most cities, and practically all of any considerable size, profit from more than one of the types of location which favor urban growth. Some, like New York, Philadelphia, Boston, San Francisco, and Seattle, are seaports with adequate contacts with the back country; others such as Chicago are inland cities, but enjoy the benefits of both water and rail connections with the areas they serve. Still others, such as the Twin Cities, Minneapolis and St. Paul, are located at the head of navigation of a great river and served by rail lines as well which, in this particular case, find crossing of the river easy above the gorge the Mississippi has cut below the Falls of St. Anthony.

City Locations and City Sites. It is sometimes true that, despite a focal location with reference to an extensive and important trade territory, the site of a city may be rather poor, but this will not necessarily prevent extensive urban development if other conditions are sufficiently favorable. Thus the inelastic limits of the original site of New York City have not prevented phenomenal growth and expansion, even across intervening bodies of water, and, though with change of name, across state lines as well. The original site of Chicago also left much to be desired, for the land was so low and flat along the lake shore that the waters of Lake Michigan formerly invaded the downtown section at times of strong onshore winds. Today, of course, this no longer occurs, for filling has not only raised the former land surface but even extended the city site into what were formerly shallow alongshore waters. Similarly, the low-lying, flat, and water-filled character of the land on which New Orleans is built makes sewage disposal difficult at all times and particularly so when the waters of the Mississippi River rise above the levels of the city streets at times of flood. The hilly topography of Pittsburgh and Seattle impose problems of somewhat different character. In Seattle, these have been solved in part by cutting down the hills and sluicing them into the Sound, thus filling in the tide flats and permitting level streets in the downtown section, at least parallel to the waterfront. Other great cities such as Shanghai and Osaka, have been similarly handicapped by their sites, yet they have nevertheless grown rapidly. Thus experience indicates that a large city will develop on a comparatively poor site, provided the location is sufficiently favorable, whereas a good site will never in itself ensure a large city.

Variable Values of a Given Location. Given locations have variable values at different periods of time. This is because the locational factor is influenced by transport, and means of moving merchandise have altered greatly since man first transferred himself and his few belongings from place to place. Today, expensive overland transport of freight on the backs of animals and by wagon has disappeared, except in the more primitive areas, to be succeeded by use of railroads. Thus a former focus of trails or caravan routes, unless it is at present also one of rail lines, has lost much of its earlier relative importance. Similarly, displacement of use of rivers and canals by rail transport has shifted locational advantage from one city to another, as from St. Louis to Chicago. Again, marked expansion of ocean transport has produced great alteration in the relative advantage of different locations, that of both Shanghai and Tokyo, for example, having improved materially during the past century.

As an accompaniment of such development, areas tributary to certain of our larger urban centers have expanded greatly. New York, for example, enjoyed only a minor locational advantage until after construction of the Erie Canal, for the region tributary to the city prior to that time was relatively limited and not notably productive. By contrast, Philadelphia, fortunately located with reference to a good agricultural area of some size, was favored, though this is not so important relatively today, since the West has developed and so much of its trade moves through New York. What has happened in the case of these two cities has occurred elsewhere as well, and doubtless will again in the future. For example, it is highly probable that, when transportation improves in China, the Han cities: Hankow, Hanyang, and Wuchang, located at the junction of

the Han and Yangtze rivers, with a roughly central location with reference to all China, as well as in the best part of that country, will become one of the world's greatest urban aggregations.

Large Cities a Recent Development. The size of any city is a direct reflection of the extent and degree of development of the back country it serves. When this is small and population is limited, a crossroads village suffices, for but few facilities are necessary to meet the demands of the people who can be reached. When a large, densely populated, prosperous, and highly developed industrial region depends on an urban center, however, it attains great size. Thus our great cities as we know them today are of relatively recent growth, for only subsequent to about 1875 has it been possible to focus the trade of any large, productive area on a single center, and important industrialization is of even more recent origin.

Thus during the Colonial period, and for some time thereafter, there were no large cities in the United States, New York having only 33,131 inhabitants as late as 1790. Similarly, Chicago, today the second largest city in the United States, had a population of only 298,977 as late as 1870; Detroit but 205,876 in 1890; and Los Angeles, only 102,497 in 1900. Other large cities were similarly smaller than at present only a relatively short time ago. Today, however, the smallest of these four cities, Detroit, has a population of nearly 2,250,000, including that of its suburbs, and the metropolitan area of New York City one of approximately 12,000,000. In the Orient, Tokyo, with a prewar population of slightly more than 7,000,000 within its corporate limits, had one of only a trifle more than 1,000,000 less than 40 years ago. Similar, though generally not such phenomenal increases, have characterized urban populations elsewhere.

The Functions of Villages and Cities. The village, which later may develop into a city, comes into existence to serve a variety of purposes. Among primitive populations, it assures a means of facilitating community activities and defense against enemies; in certain more highly developed parts of the Orient, it may serve these same ends and also permit more effective use of agricultural land. Agricultural villages likewise characterized New England occupancy during the early

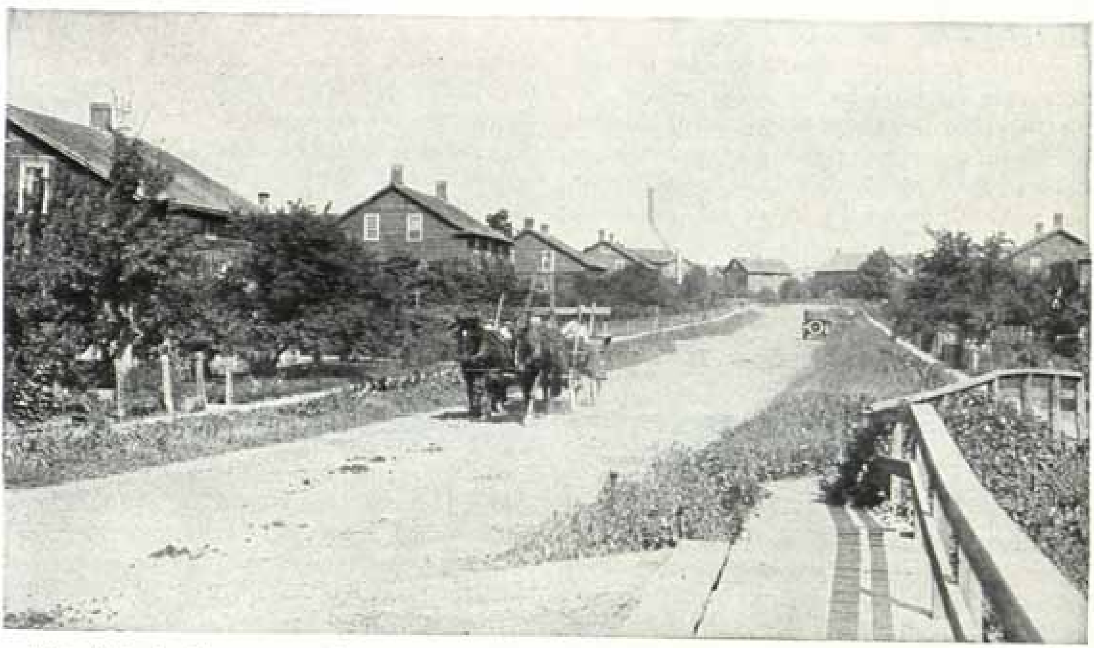


FIG. 385. Looking west on the main street of the largest of the seven agricultural villages of Amana, Iowa. This village, with a population of 437 persons, has its own school, church, stores, shops, mills, barns, and water-supply system. From it, the workers go out to the fields, with reference to which the village is centrally located.

Colonial period, in considerable part as a defense against Indians. Even today a few still persist in certain parts of the United States, and more commonly elsewhere, as in Europe. Irrespective of their original function, however, such villages serve to facilitate exchange, since they are assembly points for the merchandise of the tributary area in which surpluses can be marketed and needs satisfied to advantage. Further, individuals with special skills gravitate to such centers where employment is most certain, since customers are more numerous in the villages and temporary sojourners add to the numbers of the permanent population.

Agricultural Villages in the United States. The compact New England agricultural villages, the first of this type in the United States, were probably not a cultural heritage derived from England, from which the colonists came, but generally at least the result of choice, influenced by the necessity for defense. Certainly it is true that, in many cases, only the constant danger of Indian attack induced the settlers to dwell compactly, and that some of the early legislation was designed specifically to prevent scattered settlement. Even with such regulation, prevention of diffusion was difficult. In these villages, each "proprietor" had a lot varying from 1 to as much as 9½ acres in size, ample for a house and garden. His other landholdings, or those outside the village, were scattered, with pasture, woodland, and shore rights generally held in common. Even today, these villages still retain such relict features of this earlier pattern of land use as the village green, and dispersed lots.

In other parts of the United States, such villages have been few in number at all periods and, where occurring, they reflect certain peculiarities of the original settlement. This is true, for example, of the seven agricultural villages of Amana, about 20 miles west of Iowa City, Iowa. Established as a communistic venture in its present location in 1855, the Amana Colony was reorganized as a stock company in 1932, because continuance of communism threatened bankruptcy. The older pattern of occupancy persists, however, for the inhabitants still live in compact settlements, from which the community landholdings are worked. This permits great economy of land use without undue isolation of the farmers from the fields, and it likewise makes possible effective use of labor supply, economical mechanization of agriculture, efficient marketing of production, and probably more intelligent planning than on the average farm of adjacent areas. It also affords social contacts and permits effective centralization of schools. For this particular community at least, advantages undoubtedly exceed the disadvantages of compact settlement.

Cities and Their Classes. The distinction between village and city is not sharp, therefore the division between them must be more or less arbitrary. Thus, though the United States Census lists all incorporated places with populations of 2500 or more as urban centers, it is readily apparent that not all with more than 2500 inhabitants are cities in any proper sense of the term. Certainly, however, aggregations of 100,000 or more in the United States are not villages, but cities, for their functions are different from those of the smaller population centers. Cities, irrespective of their exact size, vary in character and in the functions they perform, but all are market centers, for, without some trade, irrespective of other favoring factors, population would not increase to the extent that a city would develop. Thus presence of a natural resource such as mineral wealth does not necessarily result in development of a city, which takes place only when trade is made possible by effective means of transportation, so that the demand elsewhere for the mineral can be satisfied from that particular occurrence. Because cities serve different functions, several classes of urban aggregations may be recognized, though the grouping must be more or less arbitrary, for the different classes merge. Therefore a given city may be classed variously, with almost equal correctness.

Commercial Cities. These will be considered to be cities where commerce and trade are the dominant economic activities and others are of secondary importance only. Such urban centers must be located at foci of transportation lines which permit assembly and dispersal of commodities for both near-by and faraway producers and consumers. Seattle is a city of this type, with commerce relatively more important than industry, even though the war decreased the difference between them. This great importance of commerce results from excellent rail connections with the interior, a fine harbor, and the concentration of shipping which facilitates the flow of trade with Alaska and eastern Asia. The Twin Cities, Minneapolis and St. Paul, particu-

FIG. 386. Looking easterly across Nashville, Tennessee, on the Cumberland River. This city is the commercial center of the Nashville Basin, one of the best agricultural areas of the South. (Courtesy of the State of Tennessee Conservation Commission.)

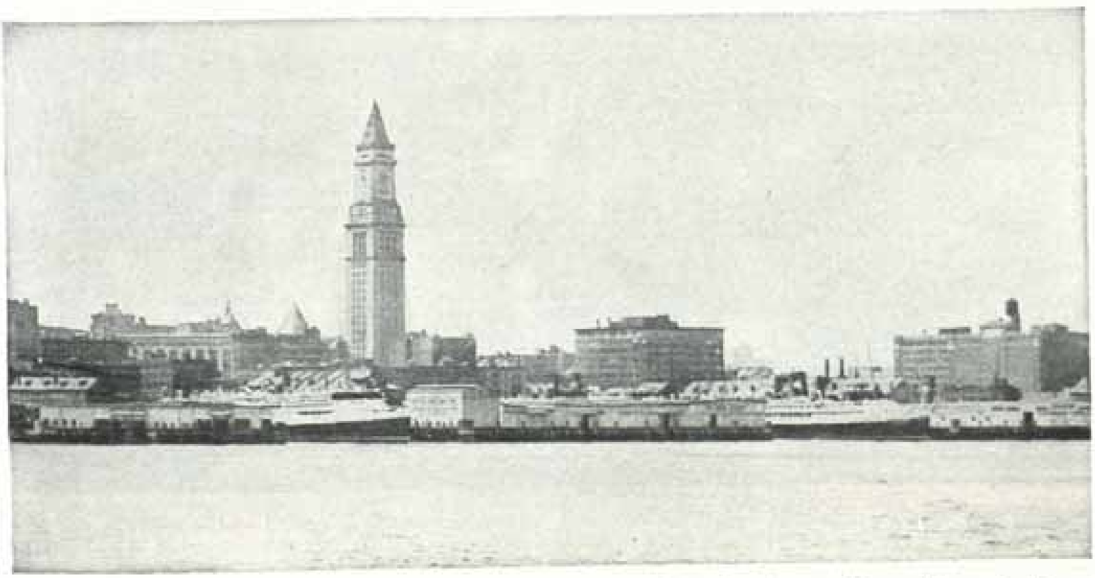


FIG. 387. The skyline of Boston, Massachusetts, dominated by the Custom House Tower. In former years, many of the greatest of American clipper ships sailed from these wharves to trade in distant regions. Today, however, manufacture exceeds commerce in importance in Boston, the hub of industrialized New England. (Courtesy of the Massachusetts Development and Industrial Commission.)

larly the latter, are likewise dominantly commercial rather than industrial centers for, though too far from essential raw materials and extensive markets for development of a high degree of industrialization, they serve as the gathering point for the production of extensive areas to their west and as distributing centers for the merchandise needed in these same regions.

Industrial Cities. All cities have industries, but they do not in all cases dominate the economic activities. This was even more true in the past than at present, for quite frequently the large city of the present is the Cinderella whose godmother is industry, a metamorphosed older commercial center. Often, of course, these industrial centers are likewise of great commercial importance as well. This is certainly true for our two largest cities, New York and Chicago, both of which are highly industrialized. It is not so true of Pittsburgh nor of Detroit, however, which did not have any phenomenal growth of population prior to extensive industrialization.

Governmental Cities. These range in size from small country-town county seats to larger state capitals, and up to that of Washington, the national capital. For minor political subdivisions, such centers are often relatively small. Thus Olympia, Washington, has less than 12,000 inhabitants as contrasted with some 500,000 in Seattle's metropolitan district; Eugene, Oregon, fewer than 20,000, whereas Portland, the commercial and industrial center, has more than 500,000, if the suburbs are included. In certain cases such as St. Paul, Minnesota, and Columbus, Ohio, the sizes are not a response to government, but to commerce and industry. However, Washington, D.C., with a population of 663,153 in 1940, and well in excess of 1,000,000 today, is a city almost completely dependent on government and, incidentally, one which has grown rapidly, for its population increased 36 per cent between 1930 and 1940, as a result of the rapid absorption of power by the Federal government and a consequent enormous increase in the number of government employees.

Resort Cities. Such cities must not only have

Fig. 388. San Francisco, an important port and commercial center, is located on the northern end of a peninsula which separates San Francisco Bay from the Pacific Ocean. (See Fig. 224.) Because of its inelastic site, a continuous fringe of urban aggregations has developed on the east side of the Bay, with Oakland the most important of these centers. In the view above, looking westerly across the Bay, the Coast Ranges of Marin County may be seen to the north, with Sausalito at the extreme right. The numbers represent some points of interest in San Francisco as follows: (1) the Embarcadero; (2) Market Street; (3) Chinatown; (4) San Francisco-Oakland Bay Bridge; (5) Fishermen's Wharf; (6) the Golden Gate Bridge; (7) the Presidio. (Drawing by Leydenfrost, Courtesy of Life Magazine.)

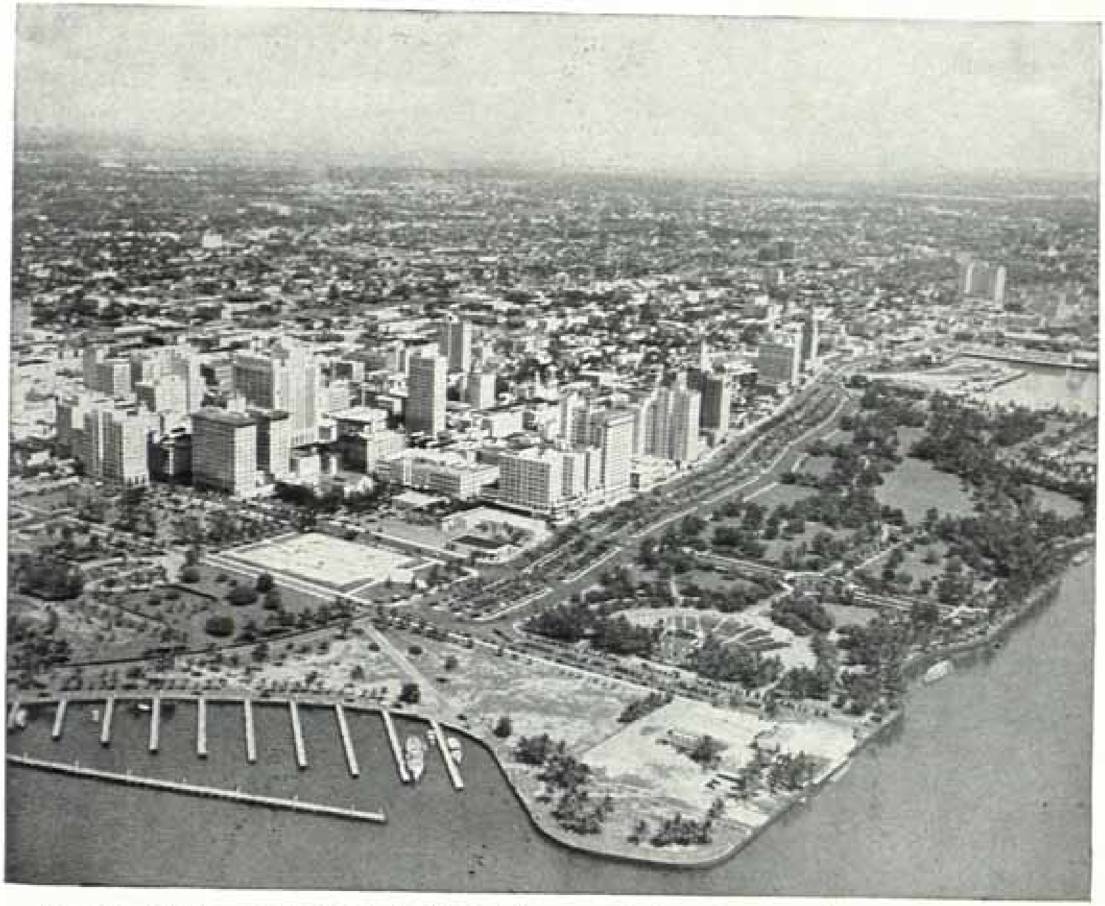


FIG. 389. Miami, on the Straits of Florida. The resort business is essentially the sole support of this Florida city, whose assets of climate and beaches have been capitalized to the extent that population increased from 1681 in 1900 to 172,172 by 1940. The illustration above is proof of the substantial character of the development. (Courtesy of the Miami News Service.)

favorable sites, of which there are thousands, but to attain any size they must be easily accessible from large population centers. Thus Atlantic City, New Jersey, has a highly desirable location, for it not only has the beach, but it is able to draw upon the millions of adjacent areas for patronage. Similarly, Miami, Florida, with a population of nearly 175,000, in addition to climate and other natural attractions, profits from the relative ease with which it can be reached by 90 per cent of the population of the United States.

Residential Cities. These are largely suburban developments which have sprung up around the outskirts of the larger urban aggregations to satisfy the demands of many for homes free from the confusion, noise, dirt, and other disadvantages of the larger urban centers, yet easily accessible to these same cities over good roads or by train. Evanston, Illinois, is such a suburb of Chicago; Birmingham, one of Detroit, Michigan. These are the places where the people sleep and where they are counted, though most of those gainfully employed may work in the city during the day.

Mining Cities. In a few cases, urban centers of some size spring up where mining is the principal and sometimes almost the only basis for support. Hibbing, Minnesota, with a population of 16,385 in 1940, discussed in an earlier chapter, is an example of a small development of this character. Butte, Montana, with a population of approximately 40,000, is dominated in similar fashion by mining activities. However, though they may attain considerable size, such centers

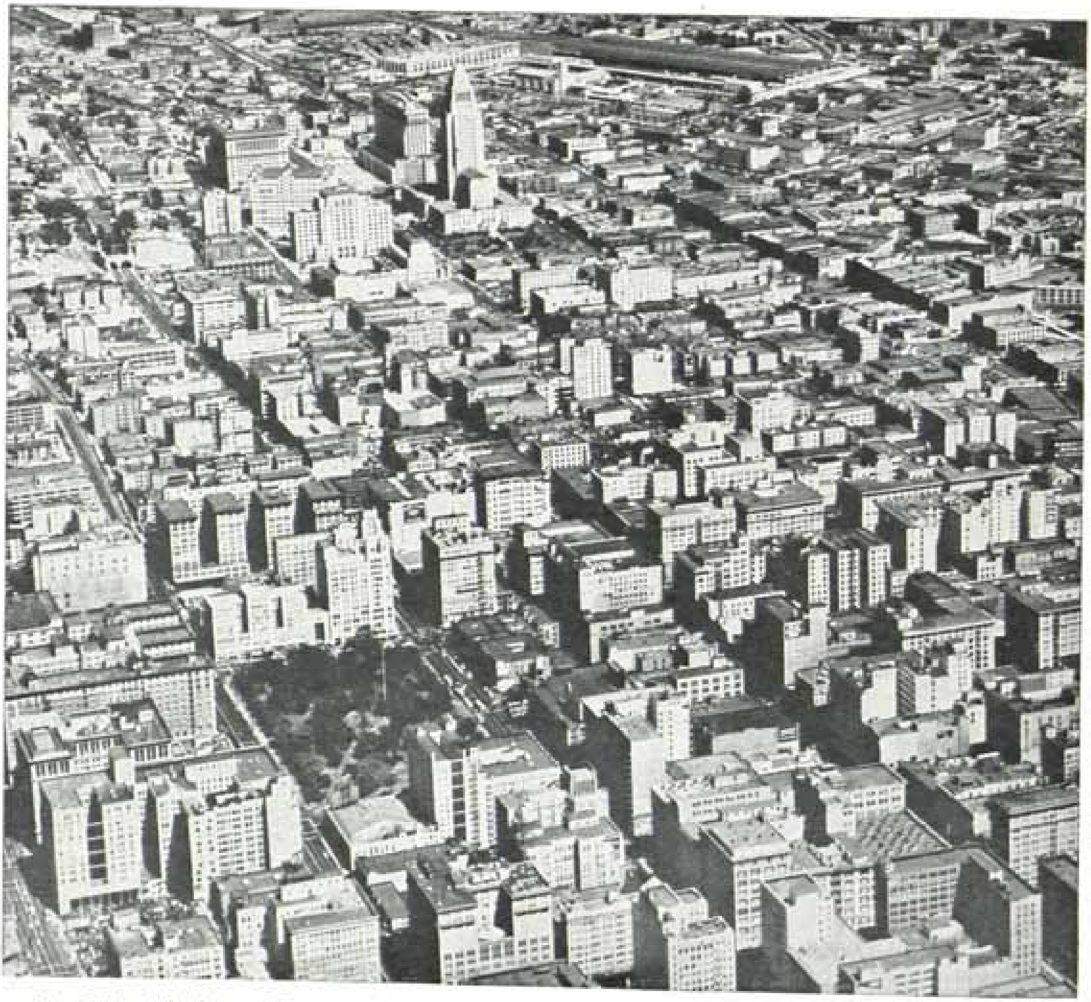


Fig. 390. The heart of Los Angeles, the metropolis of southern California, with the City Hall and Civic Center in the background. This city is an urban center of recent development, with commerce and trade the dominant economic activities in the past; extensive manufactures, especially during the war; moving pictures; and an important tourist trade. (Courtesy of the Los Angeles Chamber of Commerce.)

never become very large, nor will they ordinarily be long-lived, except as other activities may assume major importance, in which case it is not proper to class them as mining cities.

Factors Influencing City Growth. Cities expand their activities and increase in size until they serve adequately the needs of the communities dependent on them; thereafter, their growth ceases. Thus it necessarily follows that they will not continue to grow indefinitely, nor is it even true that their populations may not decrease. This last has already occurred for several of the largest American cities during the decade ending in 1940, only Washington, the nation's capital, showing any great gain during that period, and that caused by the unprecedented and abnormal expansion of governmental functions.

Not only is there an upper limit to the possible size of any city, even under conditions which cannot be foreseen at present, but the rate of growth varies for different urban centers and is not constant from decade to decade for any given city. For example, Charleston, South Carolina, has increased but little in size during the past 50 years; by contrast, Cincinnati, Ohio, has enjoyed a steady and considerable growth during

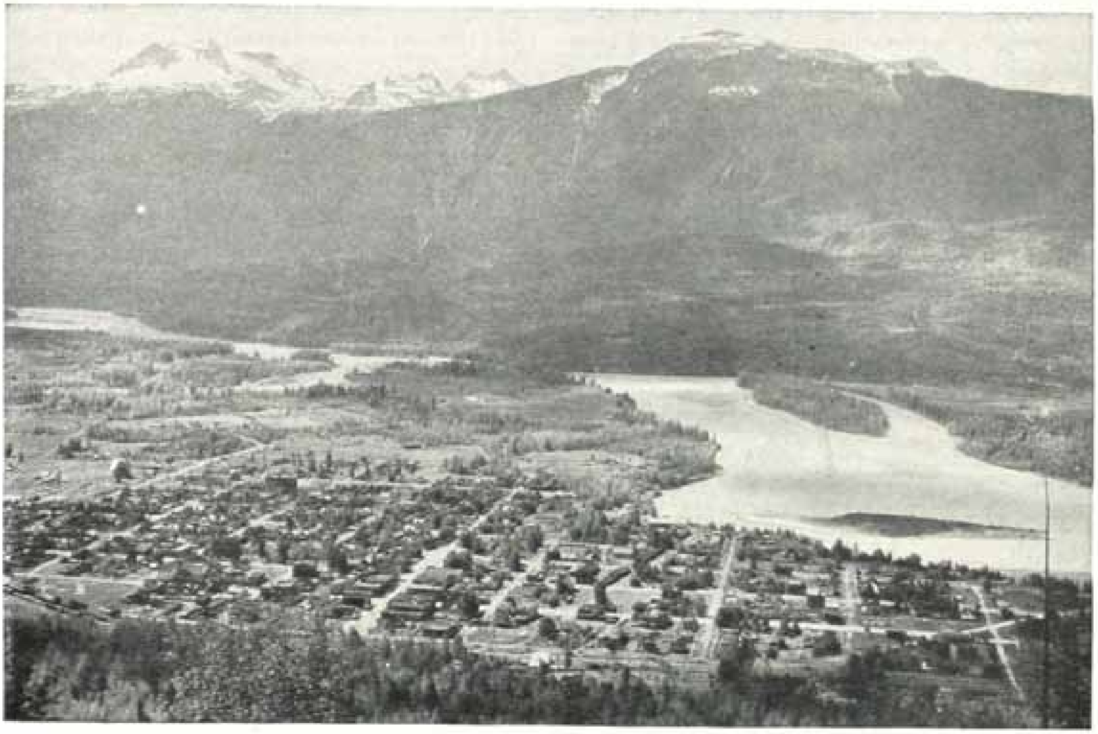


FIG. 391. Revelstoke, B. C., confined to the flat land bordering the Columbia River. (Courtesy of the Canadian Pacific Railway.)

the past century, though that of the decade ending in 1940 was less than 2000 persons. This may indicate that future expansion is improbable. Still other urban centers have enjoyed periods of steady growth, interspersed with others characterized by phenomenal increases of population. Thus Detroit, Michigan, with a steadily but gradually increasing number of inhabitants prior to 1900, nearly doubled in size each decade thereafter up to 1930, and has had a substantial growth since. For Los Angeles, increases during certain decades were even more remarkable, that for 1880 to 1890 being nearly 500 per cent, with some of 100 per cent for several others. Again, Seattle tripled in population between 1900 and 1910 and has grown since. Such increases are not confined to the United States, for Tokyo, with a population of but 1,995,567 in 1925, was by 1940 the third city in size in the world, with more than 7,000,000 inhabitants. In 1934, Richet estimated that this metropolis of Japan would have a population of 10,536,000 by 1954, at which time it would be the world's largest city. This prediction promised to be correct on the basis of what had occurred up to the outbreak of the war, which has had an unpredictable effect. Somewhat similarly, in less than half a century Shanghai has grown from a small fishing village to be one of the world's great cities, with a population of 3,489,998 by 1940. In fact, up to the outbreak of the war, it was probably the most rapidly growing of the world's large cities, as it was in the Orient, where urban growth is today more rapid than elsewhere.

Several factors operate to influence the rapidity of growth of urban centers. If centrally located with reference to developing areas of rapidly increasing population, especially where the urban as well as rural birth rate is high, the growth of a city tends to be rapid. This is true for Shanghai in China, which likewise has profited in the past from the greater security, particularly of property, afforded by foreign control. Again, in areas which have been newly opened to settlement, there may be a great increase in population and sometimes a relatively high birth rate as well.

This contributed in part to the growth of many cities during settlement of the Mississippi Valley. In connection with improved transportation, it explains that of Seattle. Accompanying development of transportation, industrialization may enter the picture, as in Detroit between 1900 and 1930, when rapid growth of the automobile industry led to a corresponding rapid increase of city population. In practice, of course, these factors rarely if ever operate singly, but in combinations. Therefore several are normally important in the growth of any single city. Thus the rapid growth of Chicago was in part a result of rapid settlement of the interior; in part, because rail lines focused on the city site; in part, a result of industrialization. This combination of factors tempted migration from rural areas to the urban center where opportunity was conceived to be greater.

City Plans. The major outlines of cities are influenced by the size and shape of the area available for urban development. Thus both New York, originally confined to an island, and San Francisco, still limited to a peninsula, have been handicapped by inelastic limits which have affected their forms. By contrast, both Chicago and Detroit have been free to expand in several directions away from the water on which they front.

In the case of many other urban centers, local topographic conditions have had marked effects on city shapes. For example, Duluth, Minnesota, located on a narrow lacustrine plain bordering Lake Superior and backed by a steeply rising upland, parallels the lake and the St. Louis River for approximately 20 miles, with a width which exceeds 2 miles in only a few places. Along many rivers and in mountain valleys, there are numerous urban centers handicapped by similarly attenuated shapes, as well as others which,

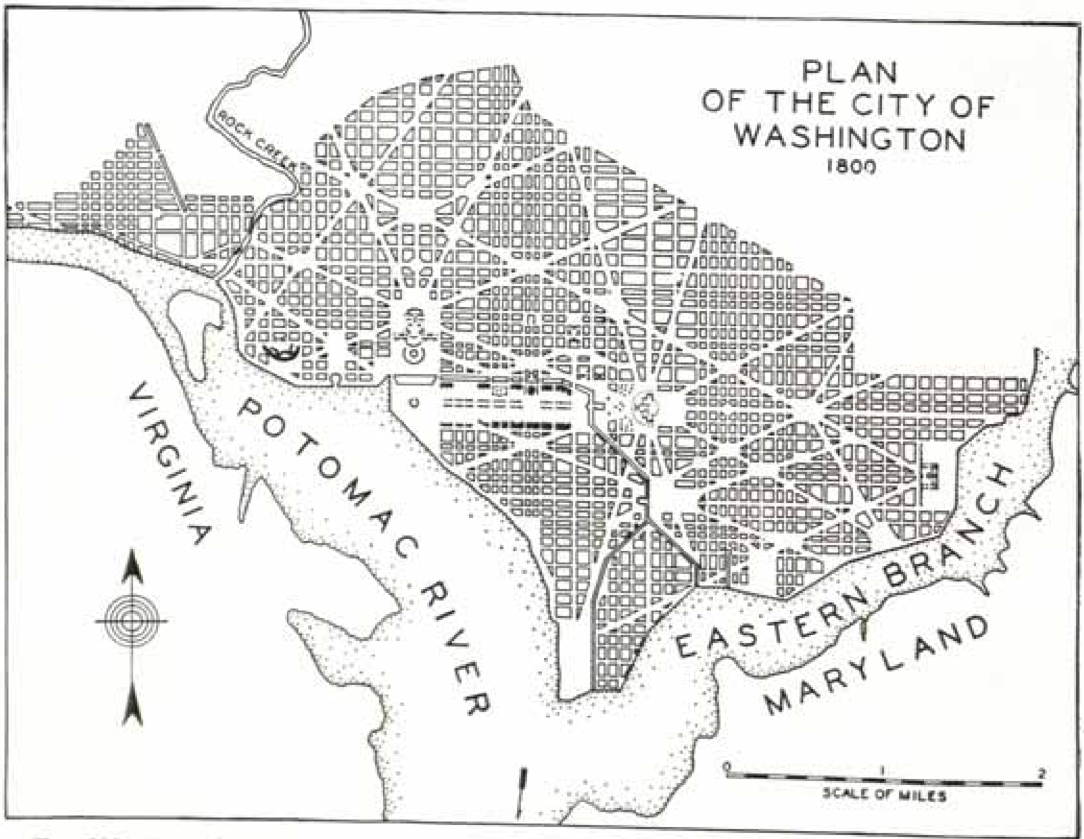


FIG. 392. Map of Washington, D. C., about 1800. The fundamental plan of Washington was outlined by a French architect, l'Enfant, and was modified by Andrew Ellicott, an American geographer. (After Atlas of Historical Geography.)

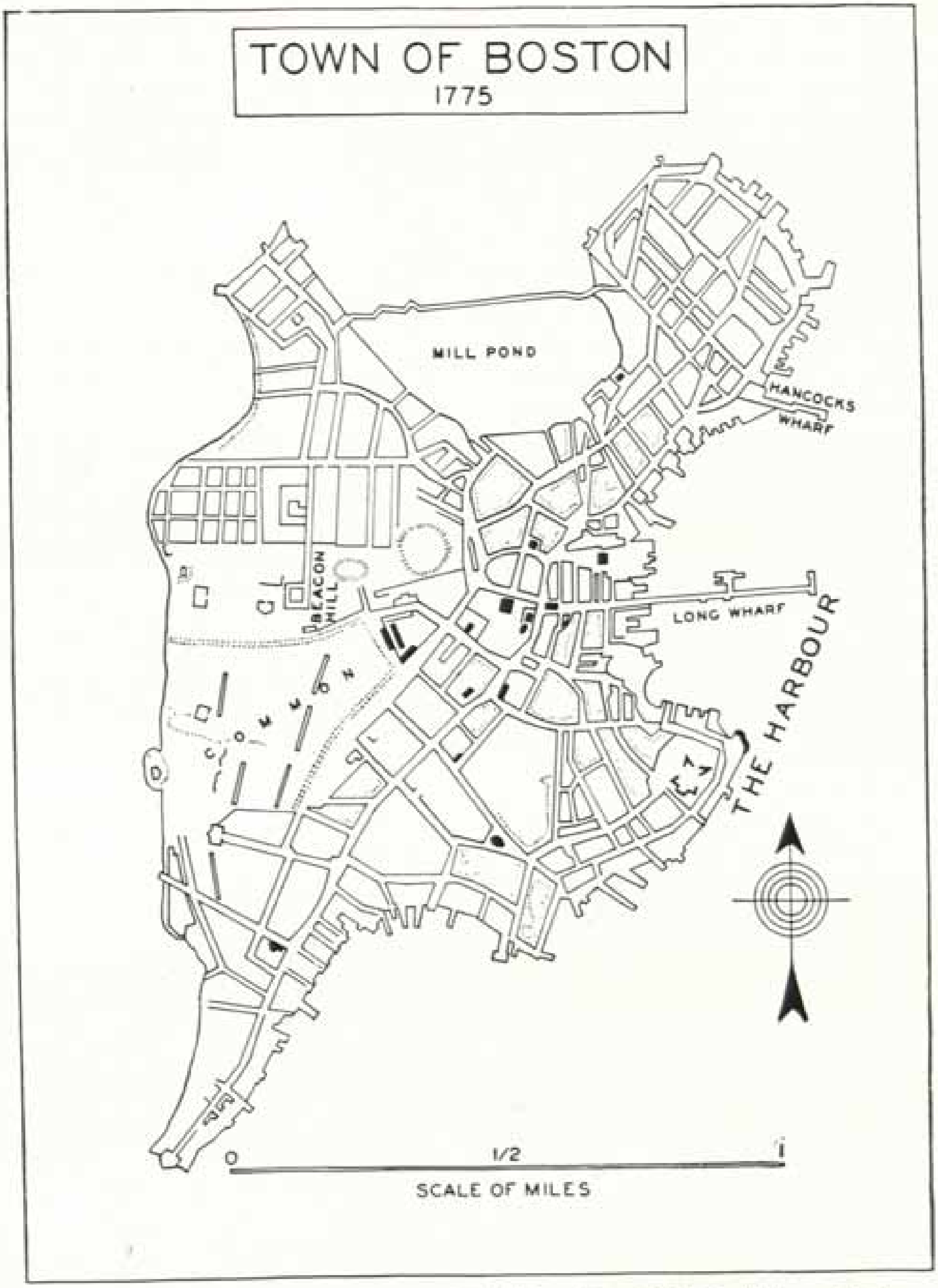


FIG. 393. Map of Boston, Massachusetts, 1775. (After Atlas of Historical Geography.)

though not attenuated, have been affected in form by the shape of the area available for use.

Such is the case for Cincinnati, which is built at three levels: that of the present-day alluvial plains of Mill Creek and the Ohio, at the junction of which the city is located; that of the terraces of these same streams; and that of the upland, all separated by grades which have affected expansion, for the rise to the upland is both steep and long. The limited extent of level land near the river, indeed, has influenced development of Newport and Covington across the Ohio, on the

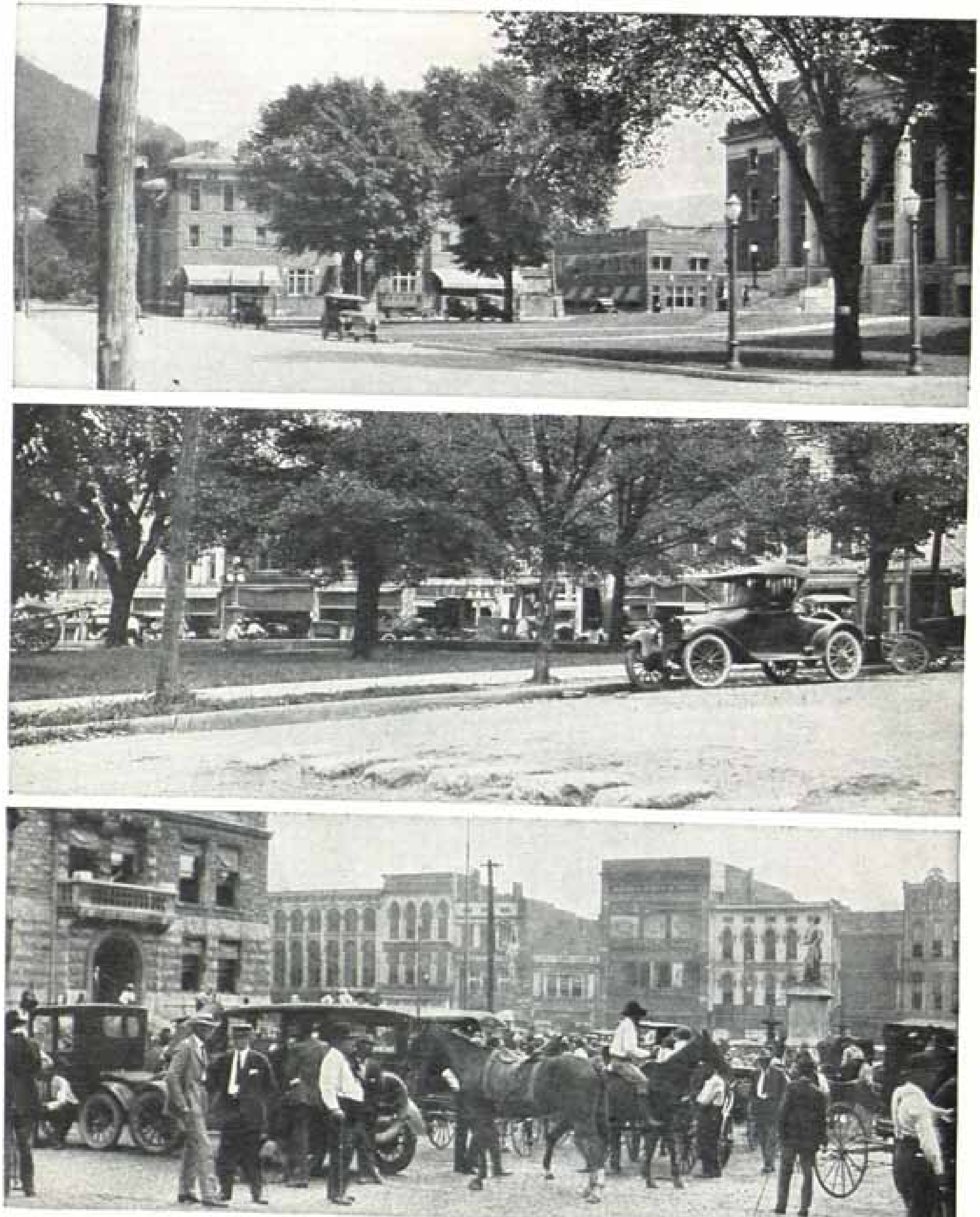


FIG. 394. Three Kentucky towns built around the courthouse square.

Top: Pineville, eastern Kentucky, with courthouse at right; business blocks in the background; hotel at extreme left.

Middle: Harrodsburg, in the Bluegrass. Courthouse square at the left; business blocks in the background; stepping stones in the street in the foreground.

Bottom: "Cheapside," Lexington, the "cheap or poor side" of the courthouse square on court day. At the left is the courthouse; in the background is the street which has today developed as the main business street, extending several blocks to the left to one of the railroad stations.

flat land bordering the lower course of the Licking. In one sense, in fact, these cities may be regarded as expansions of Cincinnati on the Kentucky side of the Ohio. The location of St. Paul on the Mississippi is similar to that of Cincinnati, for it also is built at the same three levels. The site of Seattle on the Pacific coast is likewise circumscribed, for the amount of level land along the Sound is small; steep grades separate business and the better residential sections; and the area between Lake Washington and the Sound to the west is narrow. (See Figs. 225 and 226.) Therefore the city has grown north, and to a lesser extent south, rather than east. By contrast, Los Angeles has been able to expand in several directions.

These same factors of amount of level land available and its shape, in combination with some others, also affect city plans in detail. Thus business and industry are normally confined to the flatter areas; residences preempt those which are hillier. In Seattle, for example, the business streets parallel the waterfront, rising one above another by steep grades; the industrial sections lie to the north and south, particularly to the south, along the Duwamish River and on the filled tide flats of its delta. To the east of the business section, residences and scattered small business centers occupy the hills to the shores of Lake Washington. (See Fig. 226.) The distribution of these various functional units of a city is approximately the same in San Francisco. Similarly, the important industrial, wholesale, and retail districts of Cincinnati are confined to the flat land near the Ohio River, either alluvial plain or river terrace; the better residential sections are on the upland, where free from danger of flood at high-water stages of the river. Where level land is small in amount, demand is great, and land prices are correspondingly high, the city tends to rise vertically. Thus in New York several layers of humanity are superimposed on one another in the many-storied buildings made feasible by transport, both vertical and horizontal. There, packed in caves in man-made cliffs of masonry, thousands earn their living, though they are counted by the census taker elsewhere, where they have their homes and sleep at night.

The detailed pattern of the city streets is likewise often influenced by topography, but also by other factors as well. Thus the radiating main streets converging on the City Hall in Detroit do not result from surface configuration, but from the "Governor's and Judges' plan," after the "great fire of 1805." This focuses traffic on a central point and causes serious congestion. Washington, D. C., is a somewhat similarly planned city. Again, some cities such as Boston have a system of streets that appears to be without any reason until it is realized they developed without planning, which is their reason. Still other smaller aggregations which are governmental centers are built around the courthouse square. So long as they remain small, this plan is evident, for the retail stores encircle the courthouse. When the city attains greater size, however, this relationship may disappear through development and extension of the retail district along one street, beyond the limits of the square. Though not restricted to the South, this is a common plan for county-seat towns in that part of the United States.

City Problems. With growth of large urban centers, many problems which were nonexistent or not pressing when towns were smaller become of great importance. For example, when population centers attain considerable size, the individual can no longer secure safe drinking water from his own shallow well but is forced to depend on a municipal supply, often difficult to secure for our larger cities in satisfactory quantity and quality. No longer, also, can he readily dispose of his household wastes, but he must have garbage collection and connection with a sewer system. This latter is often both difficult to construct and expensive to maintain. For many years, it is true, Chicago flushed its city wastes into the Illinois River by use of water diverted from Lake Michigan, but this, though costing relatively little, was not satisfactory, for it interfered with navigation by lowering lake levels, and there was objection from those who were affected adversely by sewage in the Illinois River. All these necessary services add to the cost of living and make existence much more complicated in large cities than in smaller towns.

Wherever large concentrations of population occur, there likewise arises a complex problem of transportation, for it is a considerable undertaking to transfer the vast number of workers, most of them arriving and leaving at approximately the same time, from the office buildings and factories to their homes, often miles away. Frequently this necessitates not only surface roads but elevated

rail lines and subways as well. Nevertheless, all are packed at rush hours. In fact, the efficiency of the large cities is often offset almost completely by the time wasted in going to and from work. Further, the coming of the automobile has made conditions worse, for streets adequate to handle the limited horse-drawn traffic of the past are often too narrow to meet the necessities of the present, especially if used by surface street-car lines. This has sometimes forced enormously expensive street widening, but even this does not always provide a satisfactory remedy, for it may be impracticable to obtain sufficient width.

In the larger cities also, particularly those not confined within inelastic limits, obsolescence of certain sections in time introduces problems for which no effective solution has been devised as yet. In any city, which must develop from a relatively small population center, the initial business district is fringed with residences. With further increase in size, stores invade the residential section and homes retreat to the peripheral portions of the growing city. Then a rooming-house section develops on the border of the business district and this in time invades the surrounding residential area, altering its character and producing another exodus to the city limits. Thus, as business expands, rooming houses, apartment buildings, and residence hotels take over the surrounding area, determining its character, and the residence section retreats before this advance, thus compelling extension of streets, water, sewer, and lighting systems to the outskirts of the city at considerable cost. Then the older business section deteriorates and slums replace the former good residences on its outskirts, but the city still continues to grow countryward, though decaying at its center. How to restore this "blighted section" still lies in the field of theory, for it has not been accomplished as yet, though many highly touted plans have been proposed. To make them effective, however, a more

Fig. 395. Karl Marx Street, Khabarovsk. This Siberian city, with its modern buildings, is located where the Trans-Siberian Railway crosses the Amur River. With a 1939 population of 199,364, it is the largest Soviet city of the Far East and one of the larger Siberian urban aggregations. (Courtesy of Sovfoto.)

FIG. 396. Three classes of urban centers are shown on this map: (1) those with 100,000 or more inhabitants; (2) those with populations of less than 100,000, but more than 25,000; and (3) those whose populations are at least 10,000, but less than 25,000. Cities with less than 10,000 inhabitants have been omitted because of the small scale of the map, inspection of which will reveal that important urbanization is limited to a relatively small portion of the United States. (After the U. S. Census.)

realistic approach to taxation policy will be necessary, and that will be politically inexpedient and possibly impossible of realization in the immediate future. It is certainly true, however, that a city cannot decay at its core, grow on its margins, and still remain an example of sound urban development.

Areas of Extensive Urbanization. Areas of extensive urbanization are relatively few in number, widely scattered, and of limited areal extent, for only under peculiarly favoring conditions will development of any great number of cities of considerable size be possible. These favoring conditions are all associated with transportation, which alone can ensure development of extensive trade and a supply of raw materials which will serve as the basis for manufactures and, at the same time, afford the means for marketing the production of mills and shops.

Urban Development in the Soviet Union. One of the most important developments of urban centers within recent years is that which has occurred in the U.S.S.R., in both Russia and Siberia. In addition to the two largest cities, Moscow and Leningrad, which had populations of approximately 4 and 3 millions respectively in 1939, there are today several others in the half million class, and many more with populations of well over 100,000. In the Ukraine, the most highly urbanized section, there are 17 of this last class. Further, this urbanization is not confined to Russia, for there are several urban aggregations in Siberia ranging from 100,000 inhabitants up to the 405,589 of Novosibirsk, the largest of the cities east of the Urals. These cities have developed where natural conditions are favorable, and in association with a planned economy. Their phenomenal growth shows what can be accomplished when the individual is subordinated to government, as in the U.S.S.R. It illustrates again what it is possible to secure—at a price. In this case, the price is surrender of individual freedom, which is much too high.

Urban Development in the United States. In the United States, 65 per cent of the total population of all cities with 100,000 or more inhabi-

tants is concentrated in 50 centers, or 53 per cent of all of that size, located east of the Mississippi and north of the Ohio and Potomac rivers. Similarly, of those with populations of from 25,000 to 100,000, 65 per cent of their inhabitants live in the same area in 178 centers, or 67 per cent of all of that size. Correspondingly large percentages of the still smaller urban aggregations are located in this same part of the United States, in which, though it comprises only about 13 per cent of the total area of the country, approximately 65 per cent of all important urban development is concentrated.

This pronounced concentration of urban centers in the northeastern part of the United States results from the fact that the largest, most highly productive areas lie east of the 100th meridian and that trade from this portion of the country funnels through cities located on commercial highways which focus on the North Atlantic seaboard. Further, the world's largest reserves of high-grade coal occur in this same area, to which iron ore from the Upper Lakes moves by cheap water transportation. Again, this area, particularly the New England portion, enjoys the advantages of an early start, which assures a reservoir of both capital and skilled labor. This fortunate combination of favoring conditions, including huge local markets, would lead one to expect the urbanization which has occurred.

Growth of Large American Cities. The decades of the past century have witnessed a general cityward drift of population and an accompanying shrinkage in the percentage and, of late years in the numbers as well, of those who live in many rural areas in the United States. In 1840, for example, the rural population comprised 15,433,496 persons and 90.5 per cent of the total

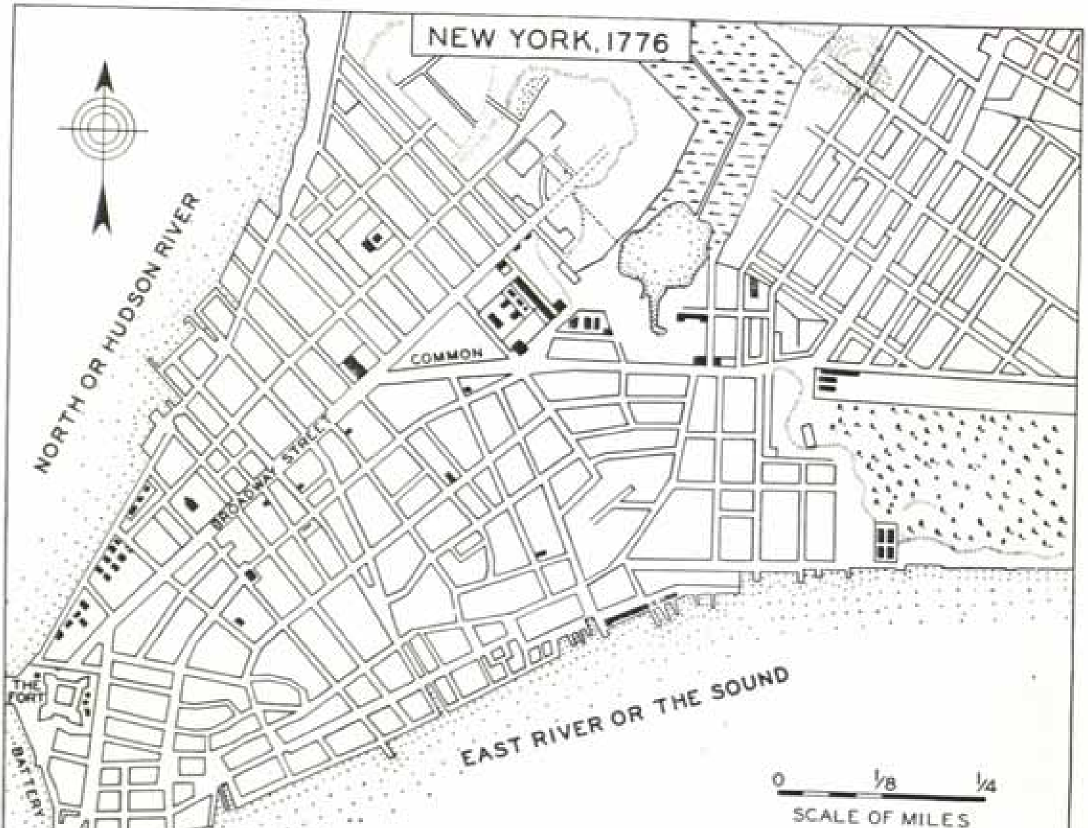


FIG. 397. The City of New York in 1776.

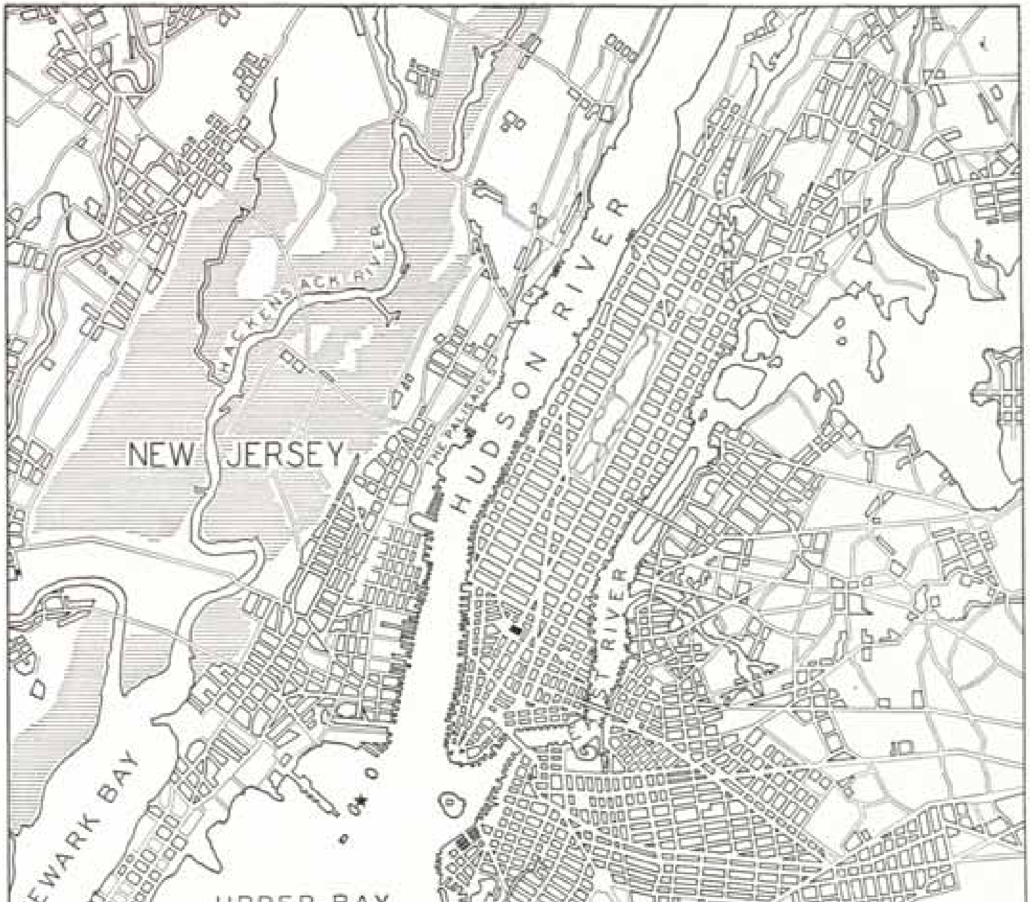


FIG. 398. The City of New York in 1940.

number of inhabitants; 50 years later, 40,649,355 persons, but only 64.6 per cent of all; and in 1940, 57,245,573 persons and 43.3 per cent of the total population. The war years have witnessed a still further reduction in the numbers of the rural component of the population, which will probably be permanent. Accompanying this change in the character of the population of the United States, several very large cities have developed. These are among the largest in the world, and each is a center of either commerce or industry, generally of both. New York City, the largest of them all, will serve to illustrate the growth and characteristics of such large centers in the United States.

The City of New York. The City of New York, the world's most important port and possibly the most perfect example of an urban product of transportation, had its beginnings on Manhattan Island, which is 12½ miles long and up to a maximum of 2½ miles in width, with a total area of approximately 22¼ square miles. To its west is the Hudson, navigable to Albany, and known locally as the "North River"; to its south and east, the East River, today lined with docks and wharves and overhung with bridges which connect with Brooklyn, New York's first important overflow; to its east and northeast, the narrow Harlem River, which separates Manhattan from the Bronx. Across the North River, on the Jersey side, lies Jersey City; to its north and south respectively, Hoboken with its piers, and Bayonne; beyond, from north to south, Paterson, Passaic, East Orange, Newark, Elizabeth, Perth Amboy, and numerous smaller aggregations of population, all essentially part of present-day New York City, though separated from it by the Jersey boundary.

When Manhattan Island was acquired from the Indians in 1626, the total white population of what is now New York City was only about 200; by the time of English occupation in 1664, this number had increased to approximately 1000; and by 1760 to 14,000. Today, about 7,500,000 persons are crowded within its corporate limits, and, including the surrounding urban centers, in excess of 12,000,000 people make up what may be known as "Greater New York." Even its cemeteries are packed, for in its largest, Brooklyn's Greenwood, sleep 441,000 dead.

Starting as a small village on the lower end of Manhattan Island, New York has expanded until it is today a combination of five boroughs: Manhattan, the Bronx, Queens, Brooklyn, and Richmond, with a total area of only 309.89 square miles, or slightly less than 200,000 acres, but more populous than Sweden, Norway, or Greece, and with more inhabitants than the entire continent of Australia. One reason for the city's rapid growth and its present great size is that 90 per cent of the 38,000,000 immigrants who arrived in the United States between 1820 and 1930 landed in New York, and many of them remained to live among their fellows in the "foreign villages" of Manhattan's lower East Side, one of the worst of New York's slum areas; the other is Harlem, the Negro section of the city.

There, in 1910, 542,000 of the recent arrivals and their children were concentrated in such villages in an area of but 1½ square miles. Because of the varied character of the immigration, at least 25 foreign languages are spoken in New York today and the city supports more than 200 foreign-language newspapers. Some who live in this section speak a foreign language only; many more, English with a foreign accent. Obviously, many think with one as well, for this area is a stronghold of foreign "isms" and radical views quite different from those of rural and more typically American portions of the United States.

Then there is Harlem, the "lodestone of the Negro," for there he may attain a position of leadership and often of affluence among others of his own color. In its 3 square miles of area are concentrated 300,000 Negroes, served by thousands of business establishments, mostly small. Often a large fraction, sometimes as much as half of this population of 230 persons to the acre, or more than 40 to an average city lot, is on relief. With such crowding and so much unemployment, living conditions are often deplorable.

Of the influx to reach New York from foreign countries, the first to arrive were the Irish, to be succeeded by Germans, Bohemians, Russians, and Italians. The last to come, though not from foreign shores, were the Negroes, attracted from the South at first by the possibility of employment at high wages, and, later, by the liberality of the relief allowance. Without these groups, and despite the fact that thousands of young people flock to New York City yearly, for this center lures the talent of the nation, New York would be smaller than Detroit and its suburbs,

FIG. 399. The skyline of lower Manhattan Island as seen from Manhattan Bridge, with the Brooklyn Bridge and the lighters and docks of the East River in the foreground. Along the waterfront are seamen's shops and saloons; beyond are the tenements of New York's poor; in the distance, the pyramids and towers of industry and finance. (Courtesy of Andreas Feininger.)

for approximately two-thirds of its population are immigrants or the sons and daughters of those from foreign shores.

New York is the great melting pot of the nation. According to J. Russell Smith, in 1920 it had "more Irish than Dublin, more Italians than Rome." It has likewise been described as "having turned out to be the Promised Land," for it has more Jews than ever did Jerusalem even in its most populous periods. Of the various nationalities, the Germans and Italians are most numerous. The latter live largely in compact settlements and are being assimilated very slowly. Larger than either of these groups, but hailing from various countries, are the Jews, approximately 2,000,000 in number, nearly half of all in the United States and more than one-quarter of all in the world today. They are widely dispersed through the city, with 975,000 in Brooklyn alone, but they are not assimilated and the possibility that they will be in the future is not promising.

For many years the population of Manhattan

FIG. 400. A rear view of New York's fine restaurants and gilded night clubs of midtown Manhattan, with the many-storied Rockefeller Center in the background. (Courtesy of Andreas Feininger.)

FIG. 401. Looking toward the lower end of Manhattan Island along the Henry Hudson Parkway, which speeds traffic and relieves congestion. To the right is the Hudson River; to the left, the many-storied city. (Courtesy of the New York City Department of Parks.)

increased steadily, reaching a maximum of 2,-331,542 in 1910, since which date there has been a steady decrease in the number of those who spend the entire 24 hours on the island. However, the daytime population continues to increase, now numbering in excess of 3,200,000, though that of the nighttime is only slightly less than 60 per cent that large. Brooklyn is likewise showing signs of having reached a stationary 24-hour population, but active growth still continues in the other boroughs.

New York has grown more rapidly in population than has the country as a whole. In 1790, it had only 1.26 per cent of the country's total; by 1840, this had increased to 2.29 per cent; by 1890, to 3.98 per cent; and by 1930, to 5.64 per cent. Today, there are nearly 2,000,000 families, of an average size of four persons, smaller than that for the entire country, living in New York City. Therefore the percentage of the nation's families living in New York is even greater than that of the total number. With such great congestion on Manhattan Island, New York has been forced to rise vertically in skyscrapers, one, the Empire State Building, reaching a height of 1250 feet in its 102 stories and affording from its top a view of 50 miles on a clear day. Facing narrow streets, these many-storied buildings, if completely emptied of their occupants at one time, would fill the open spaces near them several layers deep with humanity. Because of this great pressure on the land, it sells at fabulous prices, during boom times for as high as $340 per square foot. It is estimated that the total value of the land and buildings of the city is greater than that of all west of a line drawn through central Kansas; $21,000,000,000 worth of real estate, assesssed at more than $16,000,000,000, and encumbered by a city debt in excess of $2,500,000,000.

It is difficult to serve the vast population of

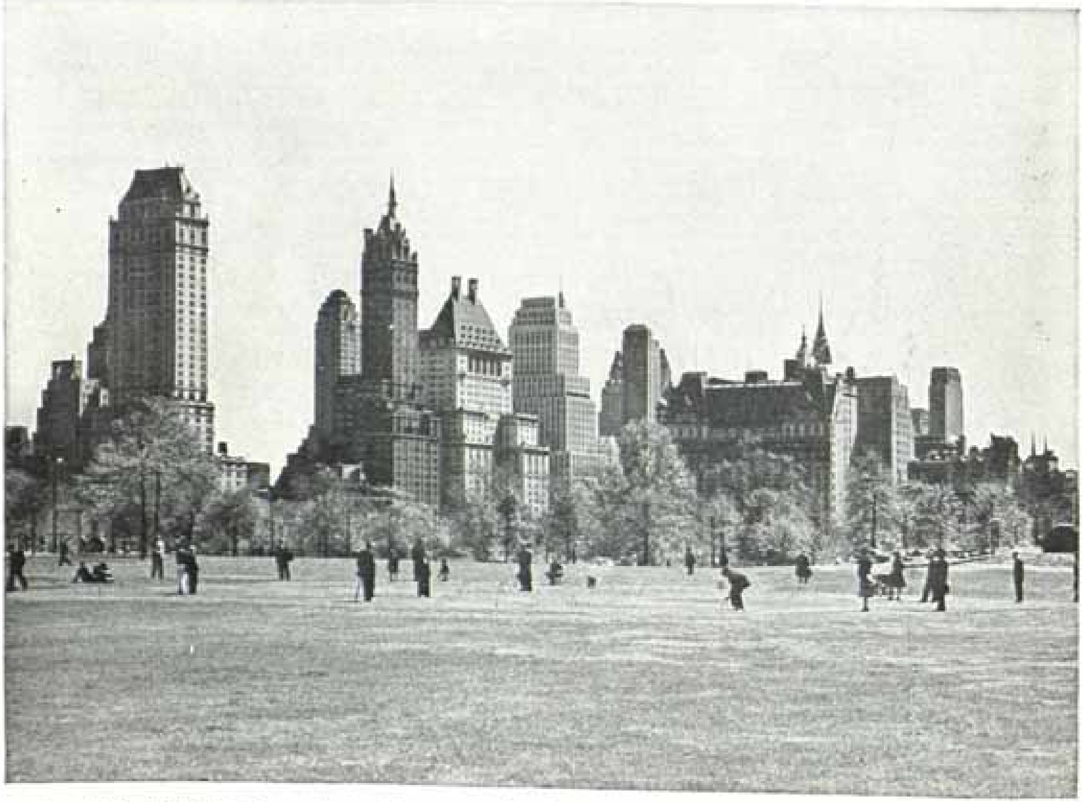


FIG. 402. Tall buildings, in reaching up to the light, cut off the light of others. Therefore they tend to cluster around open spots such as this part of Central Park, the open space in the foreground, beyond which, at the left, are the Hotels Pierre, Sherry-Netherland, and Savoy-Plaza At the right is the Hotel Plaza. (Courtesy of Andreas Feininger.)

New York City effectively, for water is consumed in enormous quantities, and sewage disposal likewise presents a problem. The many miles of streets must also be cleaned; ashes, junk, and dead animals must be hauled away each day. Underground is a maze of pipes, conduits, and tunnels. These are the "guts" and "nerves" of the city, not shown on a map but vital for its existence. To keep the city functioning requires thousands of employees, including a small army of police, and to support all these requires a city budget larger than the national budgets of many European countries.

All forms of internal transportation except airplanes have been pressed into service. These include subways, bus lines, trolleys, taxis, and boats and ferries, yet congestion still exists at rush hours. Vertical transport is afforded by elevators which handle 12,350,000 passengers each day, in addition to much freight.

The period of rapid growth of New York City, a product of transportation, began with the opening of the Erie Canal in 1825. Today, vehicular and railroad bridges, ferries, and tunnels under the Harlem, East, and Hudson rivers tie its parts together; 13 Class I railroads focus the trade of the interior on its site; and shipping operating over the major ocean highways connects the city with both the West Coast and many foreign lands. Thus New York has become the largest and most important port in the world, clearing $5,000,000,000 worth of shipping each year, with imports more important than exports, for the latter tend to move from various ports near where the freight originates.

Though trade is the most important single economic activity of New York, the city is also the most important industrial center in the United States, the value added by manufacture annually being estimated at $1,800,000,000. Yet this is less than 30 per cent of the city's total annual income of approximately $6,200,000,000, for New York is a "trading post" and "commercial gold mine" rather than a manufacturing center. Accompanying the development of such a large volume of trade and industry, New York has become the financial center of both the United States and the world.

Other urban centers in the United States, though not so large, have grown for reasons similar to those which are responsible for the size of New York. Some are supported principally by trade; others are primarily manufacturing centers; in some, both activities are important. In still others, economic activities may be of different types. All, however, are focally located with reference to highways and, to that extent, similar to New York, except that the area served is smaller and the opportunity less.

Growth of Large Cities and Suburban Development. Not only is the extent of urban development variable in different parts of the United States and for the world as a whole, and the rate of population growth of urban centers variable from city to city, but that of any particular center in a given country is subject to change from time to time. During the 50 years ending in 1940, for example, the population of the 10 largest cities in the United States nearly tripled, increasing from 6,850,442 in 1890 to 19,796,423 in 1940. However, as may be observed in the accompanying tabulation, not all of the 10 cities gained in population at an equal rate nor was the combined increase of all constant from decade to decade.

During the decade ending in 1940, the 10 largest cities in the United States retained their position of supremacy in numbers with respect to other cities in the country, but 4 of the 10 suffered a loss and none made any great gain in population. Of the next 15, however, only 3 suffered a loss, though none except Washington, D. C. made any substantial gain. This decade, then, is unique in the history of growth of American cities, for never before have our larger urban centers as a group failed to register substantial increases in size during a decade. Since 1940, the war years have affected urban growth, in some cases greatly, but whether the effect will be permanent is still uncertain.

In part at least, this failure of our larger cities to increase markedly in size during the 10-year period ending in 1940 resulted from the fact that the population as a whole is not growing rapidly, except as affected by the war. In fact, if prewar trends should continue, within a relatively few years our population will become stationary or perhaps even decrease in numbers. Further, urban population is today almost, if not quite, adequate to serve the needs of the country under present conditions of economic development, therefore there is less inducement for migration to the cities than in the past, except during emergencies such as the war when wages were

THE RECORD OF 50 YEARS OF GROWTH
OF THE 10 LARGEST CITIES OF THE UNITED STATES

Cities in Order of Size, 1940	Populations 1940	1930	1920	1910	1900	1890
1. New York	7,454,995	6,930,446	5,620,048	4,776,883	3,437,202	2,507,414
2. Chicago	3,396,808	3,376,438	2,701,705	2,185,283	1,698,575	1,099,850
*3. Philadelphia	1,931,334	1,950,961	1,823,779	1,549,008	1,293,697	1,046,964
4. Detroit	1,623,452	1,568,662	993,678	456,766	285,704	205,876
5. Los Angeles	1,504,277	1,238,048	576,673	319,198	102,479	50,395
*6. Cleveland	878,336	900,429	796,841	560,663	381,768	261,353
7. Baltimore	859,100	804,874	733,826	558,485	508,957	434,439
*8. St. Louis	816,048	821,960	772,897	687,029	575,238	451,770
*9. Boston	770,816	871,188	748,060	670,585	560,892	448,477
10. Pittsburgh	671,659	669,817	588,343	533,905	451,512	343,904
Totals	19,906,825	19,132,823	15,355,850	12,297,805	9,296,024	6,850,442

* Cities starred lost population within their corporate limits during the decade ending in 1940.

abnormally high. This is only a partial explanation, however, for many urban centers are growing more rapidly than census data indicate, and some aggregations which appear to have lost population during recent years may in reality have made appreciable or even substantial gains. This anomaly has been made possible by improved means of transportation and accompanying suburban development. This was led to slowly increasing, stationary, or even decreasing numbers within the corporate limits of the nuclear city and marked growth of the suburbs, though in a very real sense the inhabitants of these satellite population groups are and should be considered a part of the urban aggregation: the city and its suburbs, which is an economic entity. This movement of population beyond the corporate limits of the larger cities, where gainful employment is available, either into smaller satellite villages or towns, or even to small country landholdings, has been prompted by two groups of factors.

As cities increase in size, the problems which confront their inhabitants become increasingly numerous and complex and life in them is attended by many inconveniences related directly to size, such as the amount of time required to transact the smaller items of business of everyday life. They likewise become increasingly noisy and generally unpleasant, for the smoke which indicates industry means dirt as well. Escape to the suburbs is the remedy of many, for there the air is free from objectionable quantities of soot.

Again, cost of city services is high in major urban centers, for their large size necessitates many and increases the cost of all. Therefore taxes become high and living costs rise. To these unavoidable costs in large cities has been added of late a continually mounting toll for relief, a city rather than a rural problem, with the result that present taxes are often confiscatory in character and many cities have been forced to bond to the point of insolvency. This represents a capital levy. All or most of these disadvantages disappear once the corporate limits are crossed, for they are lacking in the country and practically nonexistent in the smaller towns.

Then, too, there are certain rather manifest advantages in residing outside of the large city,

POPULATION CHANGES IN METROPOLITAN DISTRICTS
1940–1946

District	1946 Population	Per Cent Change 1940–1946	District	1946 Population	Per Cent Change 1940–1946
1. New York-North Jersey	11,700,000	3	6. Detroit	2,200,000	9
2. Chicago	4,470,000	10	7. Pittsburgh	2,040,000	−2
3. Los Angeles	3,539,000	29	8. San Francisco Bay	1,996,000	43
4. Philadelphia-Camden	3,375,000	6	9. St. Louis	1,630,000	16
5. Boston	2,865,000	8	10. Cleveland	1,346,000	11

* 1940 populations are enumerations; those for 1946 are estimates only, but sufficiently accurate to illustrate trends.

where it may be necessary to live in a many-storied apartment building, for cheaper real estate makes the single house with a large yard a possibility and thus permits of gardens and flowers, which many enjoy. Life in the smaller communities is likewise more informal, which is appreciated by many, and social relationships are easier to establish. It is still true that one of the loneliest places in the world is the heart of a large city; one where it is easy to make friends and find companionship, the country and the small town. Many consider this aspect of life in the smaller communities a great advantage. Moreover, city conveniences such as water supply, gas, electricity, and telephone service are generally as available in the small towns as in the larger centers of population, and frequently in adjoining country districts as well.

With these positive advantages and the possibility of escape from certain of the handicaps of the large urban center, plus ease of access to the place of employment assured by adequate transportation facilities, it is not surprising that many are deserting our larger cities for suburban developments which promise a pleasanter place to live.

Not all cities, of course, have been affected to the same extent by this countryward movement, which has been most pronounced in our larger urban aggregations and sometimes almost absent in those of smaller size, where land prices as determined by demand are lower and single houses with large lots become a possibility for persons of relatively small means. Further, the probability of extensive expansion is related to the attractiveness of the surrounding country and its ease of accessibility by good roads or some other means which do not impose too great a financial burden or loss of time. These factors will obviously affect not only the amount of suburban development but the direction of its occurrences as well, so that these extend various distances on different sides of any given city.

Around Detroit, for example, which has changed from the pleasant residential city of 285,704 inhabitants of 1900 to a great industrial center with an aggregate population in excess of 2,000,000, there has been much suburban development. To the north, it has spread beyond Birmingham and several intermediate villages, through the Bloomfield Hills to Pontiac, itself a city of 65,000 inhabitants, and even beyond to the lakes of Oakland County, on the shores of which are several villages of some size. To the northwest, it now extends out Grand River Avenue for many miles; to the west, it stretches each year nearer Ann Arbor, 38 miles away; and to a lesser distance easterly along the shores of Lake St. Clair.

Several other large American cities have developed peripherally to a similarly marked degree. Thus San Francisco, confined to an inelastic peninsular site and handicapped by internal topographic conditions as well, has expanded east of San Francisco Bay into Oakland, today a city with approximately 300,000 inhabitants and suburbs of its own, and to its north and south in a continuously built-up shore fringe of smaller towns.

By contrast, Minneapolis and St. Paul, with a combined population of approximately 1,000,000, have had but relatively slight suburban development. Only to the west of Minneapolis, toward famed Lake Minnetonka, has this development assumed marked importance. There, the attractive, wooded moraine and numerous lakes are each year drawing larger numbers, especially of late, since the city financial structure threatens to break down under the load imposed by "social legislation." Elsewhere, suburban development has been more limited, for the Twin Cities are widely dispersed over an extensive area which affords many pleasant residential areas in the absence of extensive industrialization. Yet even with these favoring conditions, though not showing a spectacular increase, the suburbs gained 36 per cent in population during the decade ending in 1940, as contrasted with an increase of but 6 per cent within the corporate limits of the Twin Cities.

The Future of Cities. Any attempt to predict what the future holds for our larger cities obviously lies in the field of speculation, for the facts upon which a forecast must be based are limited, and it is relatively certain that some which should be available are lacking. However, it is interesting to consider some of the possibilities, even though not with the objective of arriving at a definite conclusion.

One fact confronting us at present is that our large urban centers are growing very slowly, if at all. Thus the combined population increase of the 10 largest cities in the United States during the decade ending in 1940 was only a trifle over

3 per cent, and this occurred in but 40 per cent of the 10; the others suffered an actual decrease in size. From this, it would appear probable that growth within the corporate limits of most of our largest cities will not continue, and certainly not at a rapid rate. Thus the changes which must be contemplated for the future will probably be concerned with their internal structure and relations to their environs.

Continued losses of population by most of our large cities, especially in those urban centers dependent on industrial development, as an accompaniment of increased decentralization of manufactures, is expected by some. This may be an extreme view, though it has much to commend it for thoughtful consideration. One change which will doubtless occur, though definite proof of that fact cannot be advanced, is that serious attempts will be made to restore blighted areas by increased zoning of activities and by encouragement of slum clearance. It is probable also that attainment of social objectives will play an important part in fashioning the cities of tomorrow. That the future holds change in store is essentially certain, and it is likewise probably true that urban centers of the year 2000 will generally be pleasanter places in which to live than are those of the present. Beyond this, the student is left free to exercise his gifts of prophecy, such as they may be.

QUESTIONS AND EXERCISES

1. Why are cities few in number, widely scattered, and generally small in sparsely populated areas? Does it necessarily follow that a densely populated area will be characterized by extensive urbanization? Why? What functions do compact settlements fulfill among primitive peoples? Why is initiation of urban development as we know it today deferred until sedentary occupancy is well established?
2. State the favored locations for cities. How do they vary in importance from time to time? Illustrate by examples.
3. In what types of location did the earlier great cities of the world develop? Why? Illustrate by examples.
4. Contrast Chicago and San Francisco as to advantages of location and site.
5. Discuss the relation of city location and site. Which is more important? Describe some city with a good location but a relatively poor site. Is it possible to overcome the disadvantages of a poor site? Illustrate how this has been accomplished for some city, if possible.
6. What is the probable future for urban development in China? Why? In what respects does the location of the Han cities promise considerable future growth for this urban center?
7. Why are the large cities of the present of relatively recent development? Describe the growth of some American city to illustrate why this is true.
8. What may cause villages, from which cities may later develop, to come into existence? State the functions of the early New England villages.
9. Where do agricultural villages still exist in the United States? Why? In what other parts of the world? Why?
10. What is the distinction between urban and rural population? Between a village and a city? In what respects are these distinctions relatively unsatisfactory?
11. Name the various classes of cities, giving an illustration of a city of each class. Which develop into the largest urban centers? Why?
12. Discuss the factors influencing city growth and their effect on the increase in size of selected cities, including some in the Orient.
13. What determines the major outlines of the city form? The internal features of the city plan? Illustrate by examples.
14. What problems are introduced by the growth of large urban centers? How are they solved? Illustrate by the solutions in specific cities.
15. Where are the areas of extensive urbanization located in the United States? Why confined to these areas?
16. Trace the development of urbanization in the United States.
17. Describe the City of New York, including its location, site, beginnings, growth, population, and the basis for its economic activities. Why has it become the world's most important urban development of the present day?
18. How has the rapidity of urban growth in the United States altered during the past decade? Illustrate by examples.
19. What is the basis for the extensive suburban development around many of our larger cities? Why does its extent vary from city to city? Illustrate by comparing the suburban development of Detroit and the Twin Cities.
20. Insofar as it is possible to foresee at present, what changes are in store for the larger American cities during the next century?

Chapter Forty

AFTERWORD

The earth is probably the only inhabited planet, for on the surface of no other is a fortunate combination of environmental conditions believed to occur, to provide a suitable setting for animate existence. Man shares this stage, where he plays his part in a series of shifting scenes, with other life, plant and animal: an association of interdependent organisms numbering some two or three million kinds. Some of these are predators, but even those which are not compete in some manner with others for existence, for all are parts of a related whole which has evolved through generations, extending back even into the remote pasts of geological time. All, too, are dependent on inanimate nature for their being and, in this relationship as well, there is interaction, for not only does the inanimate setting of the stage affect its animate occupants, but it is in turn modified by the life forms. In a very real sense, therefore, both the organic and inorganic elements of nature are parts of an ordered entity, bound together by such reciprocal relations as to ensure very slow and gradual change, except where man intrudes his presence.

In the continuous, age-old struggle in nature, interaction between elements of the inorganic environment, and between them, plants, and the lower animals is not directed by intelligent intent, but is physical and chemical only. Between the higher animals and all other elements though, it is something more: instinctive action by the animals with the single and direct purpose of satisfying the cravings of appetite. However, it causes no rapid change, for nature normally effects repairs after such raids on her bounty, without expulsion of the animal which causes the damage. Eventually, therefore, except where man may interfere with conscious purpose, a temporary adjustment is established in any single area, though the period of its persistence is everywhere limited, since it is subject to disturbance by a variety of factors, including some advantage gained in the organic warfare which rages continuously.

Derangements of this type may be precipitated by even minor modification of either the organic or inorganic environment, often by the action of organic agencies, of a character to favor certain life forms, thus enabling them to meet the competition of their rivals more effectively. This, in turn, may react on the inanimate areal elements and lead to still further disturbance of the former temporary adjustment. Thus, even when not subject to external influence, the environment of an area is in a state of slow but continuous flux, resulting from the competition of local life forms.

When attack comes from without, the invaders are commonly known as "weeds," sometimes defined as "plants out of place," or as "animals of little value." In areas from which such invaders come, they are held in check by long-time rivals, but when freed from their hereditary enemies and without equivalent effective competition, they embark upon a career of conquest. This is true for both plant and animal pests or weeds. Of conquest by the former, the rapid spread of the Russian thistle and bindweed or creeping Jenny in the United States affords excellent illustrations; of that by the latter, the rapid proliferation of the hare in Australia is a frequently cited example.

These weeds always succeed best where opposition is weakest, which will be where man has forced an uninvited entrance into a coordinated, adjusted society and substituted reluctant growths such as cultivated crops for species of native forms of life which have demonstrated their fit-

ness to survive through countless generations of uninterrupted struggle. Therefore it is but seldom that a solitary invader, a weed, establishes itself in a wilderness; rather it meets with success only where man has located himself and paved the way. The only notable exception to this rule is afforded by man himself, for he alone is the willful and "supremely successful weed," able to intrude effectively where others fail and to establish himself at the expense of all other forms of organic life, both plant and animal, adopting and domesticating some for his own use and destroying or modifying others to his conceived advantage.

The action of man on nature not only differs from that of the animals in degree but likewise in kind, since it is guided by an intelligent will and often directed at secondary or remote as well as immediate objectives. In practice, however, though following from determined choice, most human achievement and progress have resulted from the teachings of extensive, somewhat haphazard individual experimentation accompanied by many failures, for there are but few and relatively unimportant instances of success achieved by group planning. This may be in part because effective planning in its larger aspects requires omniscience and it is reasonable to suspect that this is not a human attribute.

Therefore, though it may be possible for man to achieve progress by a series of small, carefully devised changes, ambitious schemes for remaking the world in a short period of time may properly be regarded with a measure of suspicion. It is always well to remember that change is only something different, and that it may be for the worse as well as for the better. Indeed, if that undertaken is sufficiently extensive, the effects, if unfavorable, may even be catastrophic in character. The old proverb "haste makes waste" states a fundamental truth which has sometimes been overlooked.

In its original condition, it is true, the earth was not completely adapted to the use of man, but only to the support of species of wild life. Hence some suppression and transformation of these forms, and stimulation of artificially modified productivity are necessary to fit it for effective human use. However, man has quite generally exceeded this desirable degree of change, his destruction becoming ever more energetic and unsparing as he advances in civilization, until the impoverishment which threatens him at last brings home the necessity for preserving what is left, if not that of restoring what has been wantonly wasted. Civilized man has far too long forgotten that the earth was given him "for usufruct alone, not for consumption, and still less for profligate waste."

Thus, wherever civilized man has established himself, certain indigenous plant and animal species have been extirpated and supplanted by others; natural production has been restricted or prevented; and the face of the earth has either been laid bare or covered with new plant forms and alien animal life. These intentional changes and substitutions, though of great magnitude and importance, are, however, insignificant by comparison with the contingent and unsought results which have followed. This is because the ravages of civilized man everywhere subvert the relationships and destroy the balances of nature, thus bringing into play destructive forces previously kept in check by organic agencies which should be man's best auxiliaries. Therefore the earth is fast becoming an unfit home for the human race, and another era of equal improvidence and of similar duration to that through which evidence of that improvidence is spread may produce such impoverishment as to jeopardize civilization seriously.

During the earliest periods of his existence, man produced no such devastation, for his numbers were few, his distribution limited, and his success, even where he was able to establish himself in an unfriendly world, was not conspicuous. In this stage of his development, he modified his environment but slightly, since he neither felled the forest nor tilled the soil, nor did he deplete the store of mineral wealth or exhaust other resources. Only after some initial progress and, in increasing degree thereafter, did he become an important despoiler of nature.

When he became a toolmaker however, and as his progressively increased desires and needs compassed weapons, clothing, and other material possessions, his efficiency as a destructive agency augmented. Nevertheless, even then, his relatively small numbers, his comparatively few wants, and his inefficient weapons for long limited even the toll levied on life forms which afforded support to the earliest of populations. Further, the small reduction in the number of grazing animals effected by the demands of early man

was offset by destruction of some of the carnivora, of which they might otherwise have become the prey.

With improvement of his implements and, particularly as knowledge of fabrication and use of metals spread, man's ability to produce significant alteration of his environment increased markedly. At first, of course, the minerals used were few, but addition of others, both metallic and nonmetallic, to the number of known value increased rapidly and possibilities for effecting change multiplied correspondingly. Particularly was this true after introduction of the use of power, generated largely though not entirely by burning coal, itself a mineral.

Man plays his part on the stage afforded by the surface of the earth in varying roles: sometimes as a hunter; again as a pastoral nomad; often as a sedentary agriculturalist; and, with development of modern civilization, he engages in still other activities. He plays different roles at various times, and, again, different roles contemporaneously, for he stages a story with a plot which is repeated many times, either in its entirety or in part, in different areas.

When man became a tiller of the soil, his despoilation of nature increased apace, for to the limited levy on the fruits of wild growths was added eradication of native vegetation, to substitute in its stead, not alone cultivated crops, but useless alien plants and animal life as well, which often flourished in their new environments at the expense of the native species. In addition, there is no doubt that unwise use of the soils has decreased the extent of the arable land and the desirability and yields of that which remains in production. Not only has unwise cultivation robbed many soils of their former productivity by too heavy drains on their stored plant nutrients, but accompanying erosion, induced by unwise tillage, has stripped the soil itself, either in part or completely, from many formerly productive slopes and ruined the fertile land which borders them by deposit of sterile sand, mud, and loose rock. This is evident, not only in regions which have been long in use, such as those around the Mediterranean, but also for large areas in the United States. In many cases, these latter have passed out of cultivation within a few years after clearing from forest, to remain agriculturally unproductive for an almost unpredictable period of time, and certainly for much longer than that of white occupancy of the Americas.

Satisfaction of the progressive desires of man has resulted in such great modification of the original environment that, except by deliberate design, often but little remains of the original inheritance. Such great modification has occurred, indeed, that already the primitive aspect of the earth has disappeared wherever man lives in considerable numbers, often to an extent that reconstruction of earlier conditions is difficult or even impossible. Forests have been cleared; many species of animals have been largely destroyed; some are today extinct and known only as museum specimens. Certain kinds of plants have suffered a similar fate and others, once numerous and widely distributed, have been reduced to the verge of extinction.

We are able to see all this in retrospect, yet we cannot clearly foresee the future except to realize that additional and probably more important disturbances of the organic order are inevitable. In fact, this overturn of former conditions is unavoidable, in the same way and for the same reason that disappearance of the bison was inevitable when need for the land sealed his doom. Only the smaller life forms, often inimical to man, are still resisting and waging successful, defensive warfare. In fact, they often attack, and effectively, as witnessed by the ravages of the gypsy moth, the corn borer, and the boll weevil in the United States; the tsetse fly in Africa; and locusts in many drier parts of the world. It may even be true that man's invasion and modification of the environment favor their operations. Certain it is that, so far as we know at present, war on the insects may continue indefinitely and our success in coping with them effectively is far from certain, which suggests the important question as to what the future has in store.

This will be largely within limits of man's own determination and these limits will, as well, determine his place in the scenes which will be staged in the future, each an episode in the life history of the earth and its inhabitants. Europe has already been extensively modified; the subjugation of other continents will follow soon, but it may be well to consider critically whether all steps taken to accomplish such alterations are to human advantage, for both the present and time to come, though it is admittedly difficult to forecast the needs of future generations in any detail.

However, insofar as that is possible, it should be done and our activities regulated accordingly, for the story of the earth, its inhabitants, and their activities is a continued one, each installment or scene following logically from that which precedes. Therefore that of the future will be predicated on the one which is being written and enacted today.

Man's complex relation to his environment should be both dignified and realistic. He should recognize his oneness with nature and the obligation this confers. With respect to the organic life about him, he satisfies this responsibility best by suppression of noxious forms and limitation of his destruction of others within the narrowest bounds practicable for his welfare. He likewise has an equal obligation to utilize the inorganic elements of the environment intelligently. In practice, however, this general concept of his place in the scheme of creation is so new and often so obscured by older misconceptions that many of his activities are contradictory. Much too often, therefore, the study of science disregards the unity of nature and resolves itself into an investigation of fragments, each a miniature world in itself with its own individual problems, conceived by their students to be all-important. Thus it so happens that upon geographers, perhaps more than any single group of scientists, devolves both the opportunity and obligation to stress the oneness of nature, man's proper place in the world of the present, and the relation of past, present, and future.

We have a life interest in our heritage, it is true, but no right whatsoever to pursue a spendthrift policy and squander the birthright of the race, without responsibility to future generations. Certainly we have some obligation to our successors, and therefore we should not, like children, take whatever the present offers with no thought of what the future may hold, for those who later look back on our deeds will not hold us blameless if we follow such a course. They will regard us as spendthrift at least, if not worse, even as we are today inclined to regard the primitive agriculturalists of the tropical forests and the early planters of Virginia, with their wasteful use of virgin soils. Civilization, indeed, cannot properly be considered to have reached full development until sterilization of the environment is abandoned as a practice and reconciliation with it has made more substantial progress. Up to that time, we may logically be considered to have attained to no more than the later stages of barbarism, during which period of development the present only is of paramount importance and consideration of what the future may hold in store is deferred until necessity forces, often too late for effective action.

Though it is late, it is still not too late for man to take steps to so adjust his activities as to profit most effectively from the opportunity nature offers. However, this will be possible only when realization is common that man cannot conquer nature; that he exists only by her suffrance; and that his activities must therefore be regulated with that fact in mind. It is not too late, for the world is still in its youth; it may well be the home of man for a period of time which will make man's previous history seem short indeed for, barring accident, life may persist for 100,000,000 years or more, so far as can be foreseen at present. This is true at least insofar as the physical conditions of nature render this a possibility, for geological change is exceedingly slow. Neither the climate nor the atmosphere, nor the heat of the earth, for example, has changed greatly in recent geological time, which far exceeds in length the period of its human habitation. In fact, the most important element in determining the life of the human race on the earth is probably the character of man's activities.

That intelligent action is beneficial may be illustrated by the reclamation of the Landes or heath of Gascony in southwestern France. This 5400 square miles of former moorland and marsh was once a sandy waste, underlain by an impervious subsoil of tufa or "alios," and therefore so swampy that the "Landesats," the inhabitants, could traverse it only on stilts. Dry in summer, drowned in winter, it afforded only scanty pasturage for a few flocks. To add to its handicaps, this plain was subject to invasion by drifting sand which buried the soil and plant life and threatened extinction of all occupancy, for dunes, 100 to 300 feet high along the ocean, driven by the wind, advanced to cover fields and houses. About the end of the eighteenth century, 1600 miles of ditches were dug and 1,600,000 acres were planted to maritime pines and oaks. These arrested the drifting sand; agricultural improvement became possible; recovery of the waste was assured. Today, disaster no longer threatens.

In considering the geography of today, we are

concerned primarily with current scenes and environmental elements, for it is subject to the limitations of this setting that present human activities are prosecuted. However, it should be realized that there is continuity in areal occupancy and activity. This is indicated by study of the geography of earlier periods. Therefore knowledge of the past is often fundamental for a satisfactory understanding of the present.

These scenes, the parts of which are the various economic activities of man, manifested in both action and material results in the cultural landscape, make up the play, staged in its entirety in a physical setting on the earth's surface, and largely on the land. Seldom does one economic activity alone occur; normally, several are present. Thus, even in highly industrialized areas, there may be some associated agriculture, mining, and other industries; or in another type of region, dominantly agricultural in character, mining and some industry may afford part of the support of the population. Even in very dry areas such as the Kalahari, some of the population may carry on certain activities such as agriculture, difficult to explain except as a cultural inheritance. Only on the most extreme of the frontiers of human occupancy such as areas of polar cold do we find only one economic activity present, and not always even there.

Man's spread over the face of the earth and the extension of his activities are restricted not only by nature but by cultural inheritances as well, for the latter always play a part and are often the most important factors in establishing the limits of possible human advance. Seldom indeed does nature exclude the possibility of human support completely, even in the driest of deserts or the most inhospitable of polar areas. However, if man insists on making his living in some manner inherent in the culture of the group of which he is a member, and necessary for its continuance, human occupancy may became impossible under those terms.

The simpler the culture, the greater and more obvious are the restrictions imposed by environment. Thus the Eskimo, who live largely by sea hunting, exist only where this activity is possible. Similarly, the Chinese find only those areas satisfactory which afford the possibility for carrying on agriculture with Oriental practices, though this eliminates from use much land that we would consider entirely suitable for production. By contrast, the more complex the culture, the greater the variety of areal conditions which permit man's support. Therefore no other culture is so able to utilize varied opportunity effectively as that of the industrialized Western nations.

It alone makes varied occupation possible and extensive urbanization feasible. Further, its spread, particularly marked of late, has tended to eliminate with each decade the former variety of the world's occupancy. Nevertheless, study will always reveal the skeleton of the past, which supports the structure of the present, beneath the veneer which Western industrial civilization has superimposed.

But such emancipation from crippling environmental limitations always increases the interdependence of populations, sometimes diverted into artificial channels by attempts at national self-sufficiency which interfere with the free flow of trade. This interdependence of the populations of the earth is brought home with redoubled force when the open hostilities of military warfare impose restrictions on the normal movement of commodities. Then we are prone to speak of certain materials which we lack as "strategic," though they are equally strategic in times of peace. Thus we then think of manganese, for example, as a strategic metal, though only a few pounds are necessary to make a ton of steel; for without steel, modern war cannot be waged successfully. However, it is equally true that manganese is a strategic metal in times of peace for, without it, modern industrial development would be impossible.

Further, it is not alone the metals which are strategic materials, for food is certainly fundamental for military operations; forest resources must be drawn on extensively to enable fighting successful campaigns; and many of the animal products of both land and water afford raw materials, useful in times of war as well as when peace prevails. When one considers the facts, it is apparent that it is the huge-scale movement of varied commodities, not minerals alone, which makes both modern military wars a possibility and peacetime pursuits a reality.

Thus with the present organization of Western industrial development, there must be continuous economic warfare between nations, for equitable access to and division of the world's wealth of land and water does not exist and will not become a fact until human nature and national

ambitions as manifested by government alter more than appears possibie within the lifetime of the present generation of man. These are the teachings of the past which cannot be disregarded without recourse to wishful thinking as a substitute for acceptance of realities, and without courting certain embarrassment and probable actual danger if such idealistic thinking should be implemented by surrender of our heritage of natural advantage. Certainly the "have" nations possess an opportunity to use their resources as a means of keeping the peace and, for the present at least, this seems to hold forth most promise as a method of limiting the incidence and spread of war.

This economic warfare, which rages continuously, determines to a large extent both the volume and direction of flow of trade. Thus in times of peace we restrict movement of certain commodities by price regulations, sometimes called "tariffs," which may constitute practical embargoes without the necessity for so designating them. In this manner we wage economic war on those we desire to handicap, while at the same time favoring others by preferential agreements when we believe these to be to our advantage. In times of peace, such restrictions may not be obvious to the average individual, for they are purposely disguised to avoid undue friction; in times of military conflict, this is not the case, for it is then advantageous to have all appreciate their effects. Therefore they may masquerade as "sanctions," which accomplish no more than a prohibitive tariff in times of peace.

With less direct dependence on the soil, and particularly where such reliance does not enable complete support of existing population, the importance of control of adequate supplies of raw materials and the necessity for the free flow of trade increase apace. Today it is so great among all advanced populations that access to and success in securing such necessities, not the amount of cannon fodder alone, measure military might. This does not mean potentialities in these respects, however, but actual development of access and means of supply, so that they may be available when needed.

The world's geography is therefore a potent force in either ensuring peace or waging effective war, for only those nations which *have* can enforce the peace or fight successful wars, even those of defense alone. Therefore we should assemble adequate data with respect to the resources of the earth we inhabit so that we may be able to better adjust our activities to the newly emerging relations of the present, when distances have disappeared and isolation is no longer possible because of that fact. Further, this is doubly important because the future holds promise of an even greater interdependence of populations in the day which has only dawned as yet.

One of the peculiarly disturbing developments within the past few years has been the apparent lack of a predictable pattern in the changes which have occurred. This was not so true in the past, and it is perhaps in part a result of the stage of progress of the human race which has introduced problems which most persons, including even those in public office, find beyond their ability to solve effectively. If this is correct, and some believe it to be so, it introduces a real question as to what man's future may be.

Upon the student of geography devolves the responsibility to assist in solving these problems, for it is these changing scenes which result from the impress of successive civilizations that are his principal concern. He describes them; he attempts to explain or interpret them; he may even venture to forecast the future, with limitations. It would be a narrow view of the subject indeed which excluded man and his varied activities, even though the major objective were only to obtain a knowledge of the solid and fluid masses which constitute the earth, for all are affected by man, who is so largely a destructive agency. Thus the study of both man and his environment becomes necessary for a proper understanding of our assets and our problems, a study of the earth according to its areal differentiation, which is geography, the one subject among the sciences whose field compasses, not a "microcosm," but the entire surface of the earth.

PART SIX. APPENDIX

Chapter Forty-One

THE DEVELOPMENT OF MAPPING

The Earliest Maps. Paralleling early speculation as to the shape of the earth and measurements of its size, attempts were made to represent its known surface by maps. The oldest of these which have been preserved, made approximately 2500 years before the birth of Christ, were extremely crude. They were actually diagrams on clay tablets rather than maps as we know them today. Doubtless still earlier representations of the surface of the earth were made, but of these we have no record. We know, however, that primitive populations, particularly if nomadic in their habits, map crudely in graphic form the areas with which they are familiar. Thus Arctic explorers, Parry, Ross, and others, profited by such "picture" maps made by the Eskimo; Cook, by maps of Tupaya, a Tahitian; and the Spanish explorers, Cortez and Pizarro, by the maps of the Aztecs and Incas. Inasmuch as we know of these and other similar maps made by less advanced populations within the period of history, it is fair to assume that, long before the dawn of civilization, other populations of a comparable stage of development made similar maps. The fact that none of these has been preserved does not decrease the probability that such maps were made and used.

Early Greek Maps. By the time of Herodotus, about 450 B.C., the known world of the Greeks embraced the lands bordering the Mediterranean and extended as far to the east as India. Maps of this period, though inaccurate, portrayed the Mediterranean lands in recognizable shapes. By 200 B.C., the known world had expanded to include the British Isles, and maps with crude parallels and meridians had been produced. For example, Eratosthenes' map of the world had a middle parallel which passed through the Strait of Gibraltar, six other parallels, and seven meridians, though the spacing of these lines is not like that on any map of today.

The Beginning of Mapping by Modern Methods. It remained for Claudius Ptolemy, a mathematician, astronomer, and geographer who lived and worked at Alexandria about the middle of the second century after Christ, to devise a scientific system of parallels and meridians. Though based on insufficient and inaccurate data, it is true, his use of these lines was fundamentally that of the present. He, for the first time, used the terms "latitude" and "longitude" in association with his greatly improved method of map projection. His work, neglected by the Romans, whose maps were not based on scientific procedure, became one of the foundations of geography during the Medieval period, its influence persisting until the close of the sixteenth century. Ptolemy's work became known in western Europe after its translation into Latin in 1410 A.D. It was first published in 1475 A.D. In all, seven editions were issued, ample evidence of the esteem in which it was held at that time. The earliest printed geographies of the fifteenth century were not only patterned after the system of Ptolemy but they were as well in considerable part only translations and amplifications of his work. They were even known as "Ptolemies."

Errors in the Early Maps. A fundamental difficulty with all the early maps of the world was that they were based on insufficient and inaccurate data. Methods and instruments for the precise determination of position, that is, latitude and longitude, are essential for accurate mapping and these were not available. Crude instruments for securing latitude were in use as early as the time of Eratosthenes, but accurate measurements were not made until 1526 A.D. Accurate determination of longitude is even more

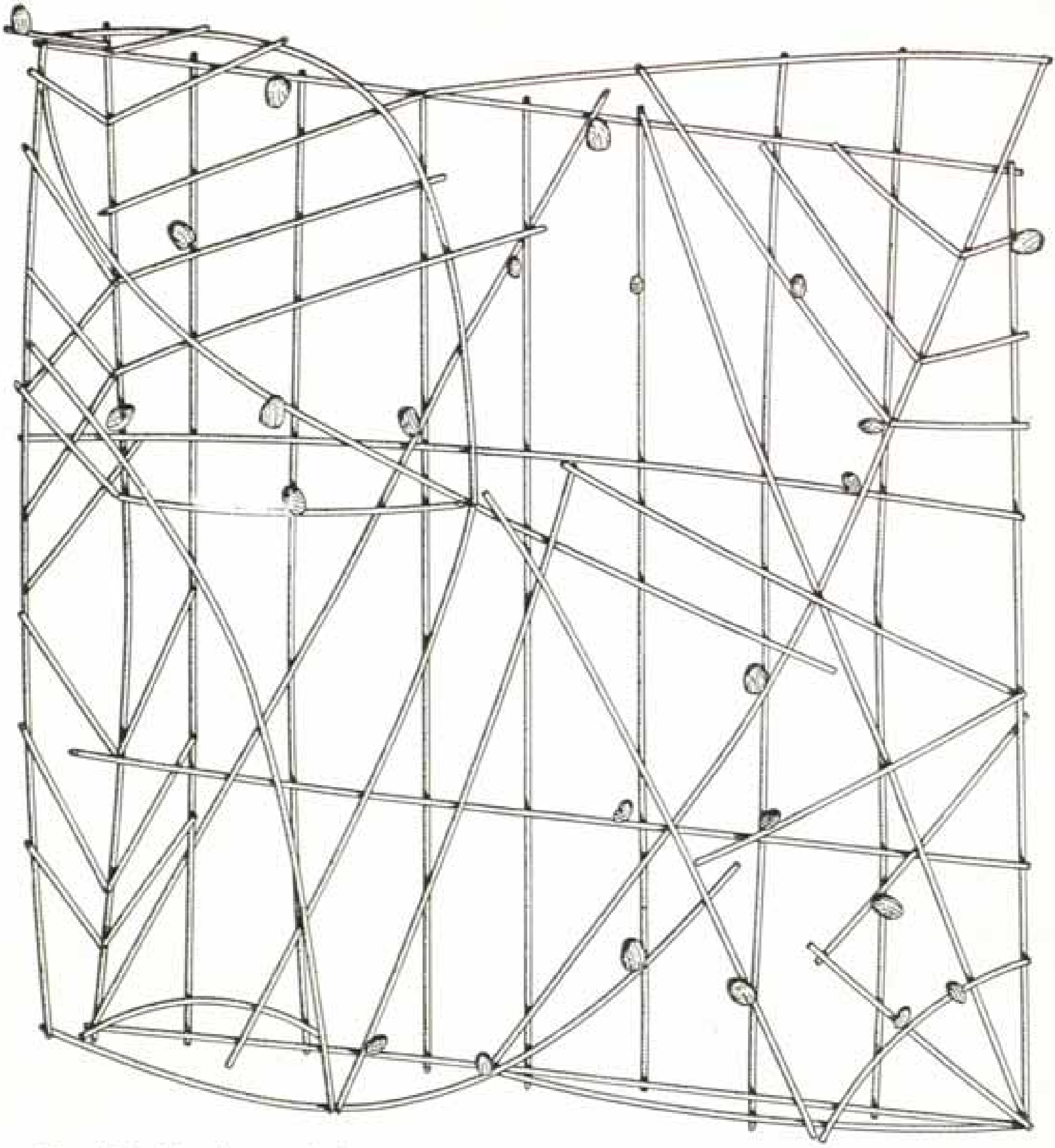
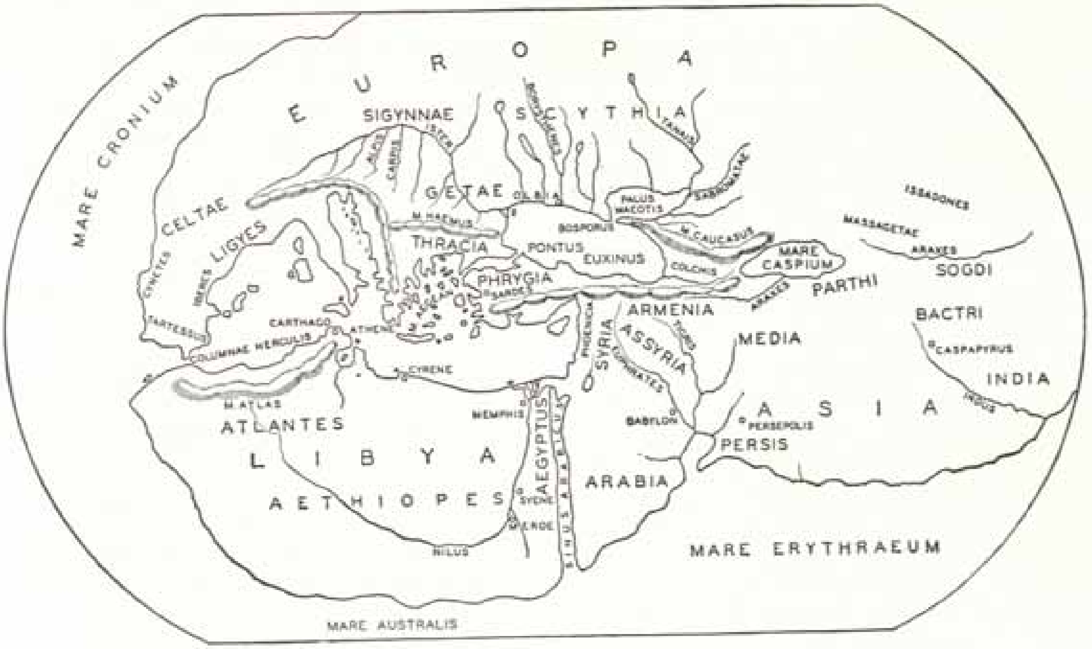


FIG. 403. Map chart made by the Marshall Islanders of the Pacific. The shells represent islands; the framework is partly to permit support and proper spacing of the shells, partly to show the prevailing curvature of the wave fronts. (Courtesy of the Geographical Journal, October, 1928, London.)

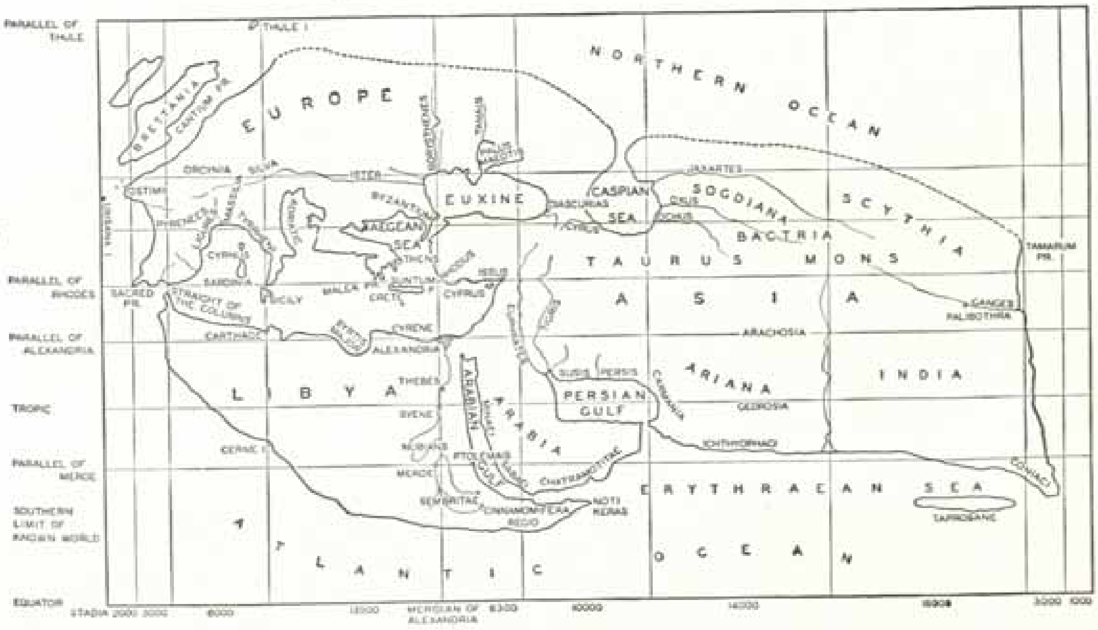
difficult. Not until 1735 A.D., with the invention of the chronometer, was it possible to ascertain longitudes satisfactorily and precisely. Thus, during the period from about 250 A.D. through the Medieval period, maps were necessarily inexact. Some, like the earliest ones known, were diagrams rather than maps, and pictures of living creatures, both land and sea animals, appeared on them. For hundreds of years it was necessary to leave the interiors of continents such as Africa and Asia blank or fill them with imaginary rivers and lakes. Today, by contrast, there are few parts of the world of which this is true, and such areas shrink continually in extent.

Maps of the Medieval Period. The maps of the Medieval period were of two classes: the church-



HERODOTUS 450 B.C.

FIG. 404. The world according to Herodotus. (After Times Atlas.)



ERATOSTHENES 240 B.C.

FIG. 405. The world according to Eratosthenes. (After Dickinson and Howarth.)

men's and the sailors', or "portolano maps." The latter were coast-line charts, dating from about 1300 A.D. and compiled in part before there was knowledge of the compass in Europe. By 1500 A.D., these latter maps had attained a considerable degree of accuracy insofar as coast lines were concerned. Later, by extension of the mapped area inland, they were expanded into world maps. During this period, however, maps were unscientific, except for the portolano charts, and even these were unreliable away from the actual coast, for no attempt was made to employ latitude and longitude to plot the exact location of places.

By 1500 A.D., many tolerably accurate maps of small areas had been produced, but it was not until 1617 that the modern methods of survey had been perfected which made accurate maps of larger areas possible. By the seventeenth and eighteenth centuries, maps based on such surveys were in existence for most of western Europe. By 1700, Delisle had produced a cartographic masterpiece for this period in his map of the world and, somewhat later, D'Anville finally eliminated the fantastic rivers and imaginary lakes from his map of the world, leaving the interior of Africa blank. This marked the final disappearance of the Ptolemaic influence.

Development of Mapping in the Far East and the Moslem World. Mapping developed independently in the Far East at least as early as the third century B.C., but unknown to the Western world until hundreds of years later, and with no effect even then, except as available data enabled compilation of atlases such as that of the Chinese Empire by the Jesuits. Even the rise of Moslem culture between 700-1400 A.D., though marked by the production of gazetteers, accounts of travels, and speculation concerning the function of environment in human affairs, had little or no effect on Western mapping practice, for graphic representations of the earth's surface by

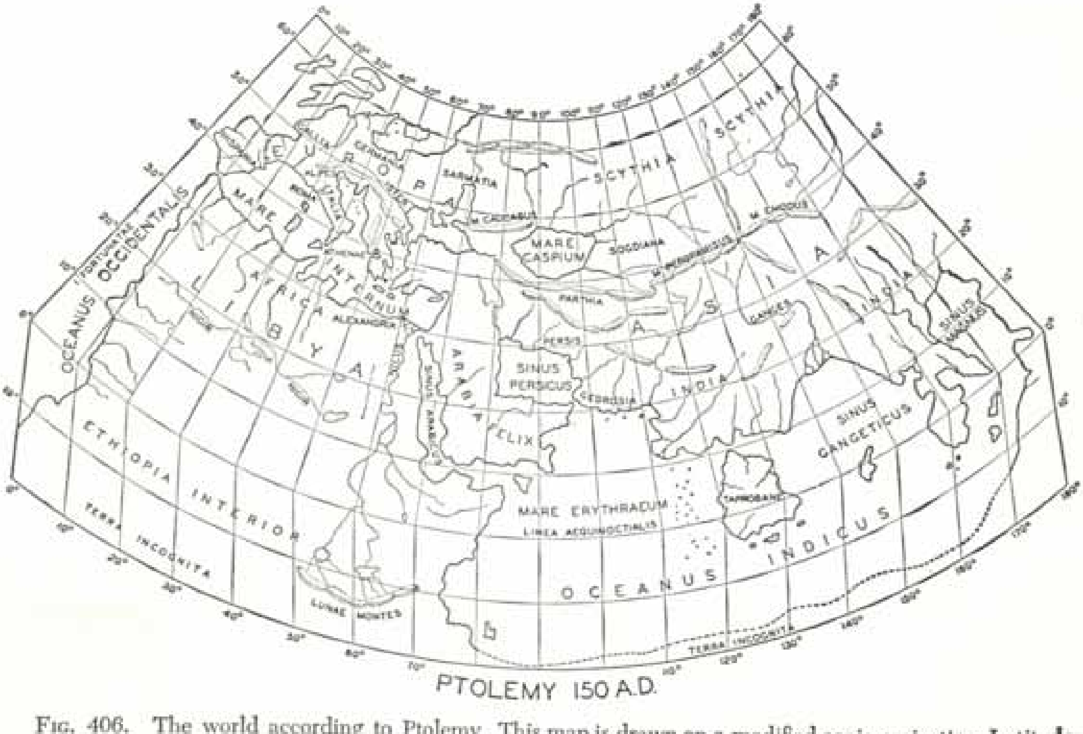


FIG. 406. The world according to Ptolemy. This map is drawn on a modified conic projection. Latitude, or distance north and south of the equator, is shown in degrees at the right and left; the 180-degree longitudinal extent of the known world at that date at the top and bottom of the map. It will be noted that, though latitude is reckoned from the equator as it is today, the principal meridian, or the one with a longitude of zero degrees, passes through the legendary Fortunate Isles, probably the Canary Islands, whereas the one in common use today is the meridian of Greenwich. (See Chap. XLIII.)

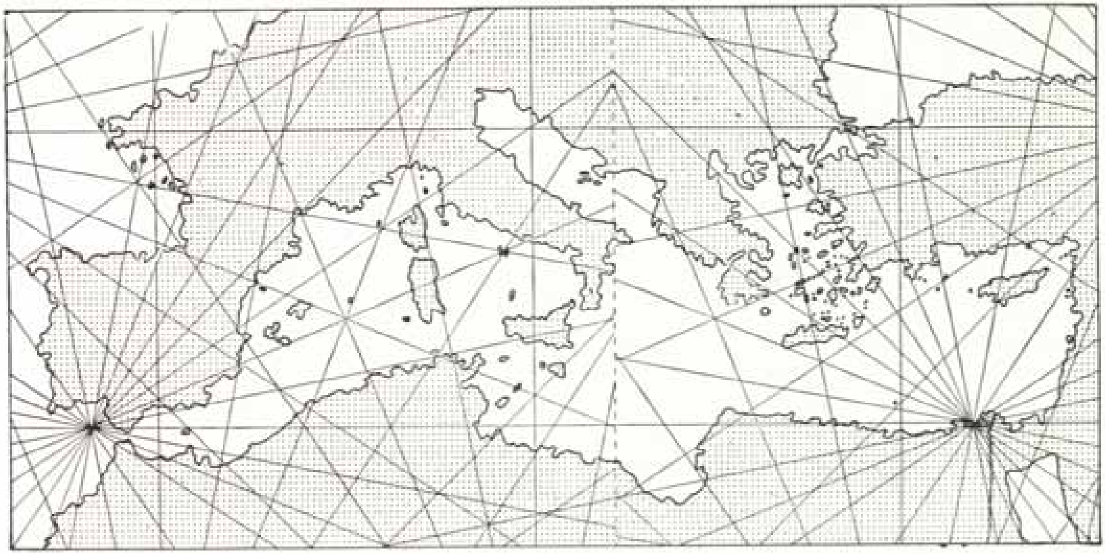
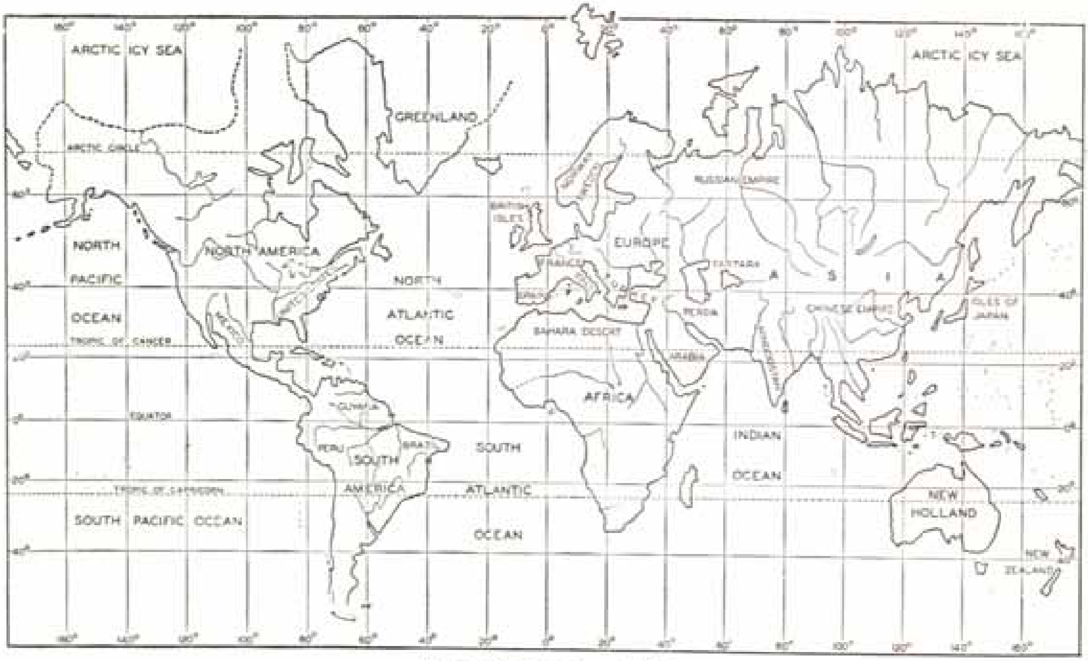


FIG. 407. Portolano chart of the Mediterranean, 1500 A.D. (After Dickinson and Howarth.)

FIG. 408. Mercator chart of the world, 1569 A.D.



THE WORLD c.1800

FIG. 409. The world as mapped about 1800 A.D., drawn on a Mercator projection. By this date, the outlines of the continents were portrayed with considerable accuracy, and the principal meridian used was that of Greenwich.

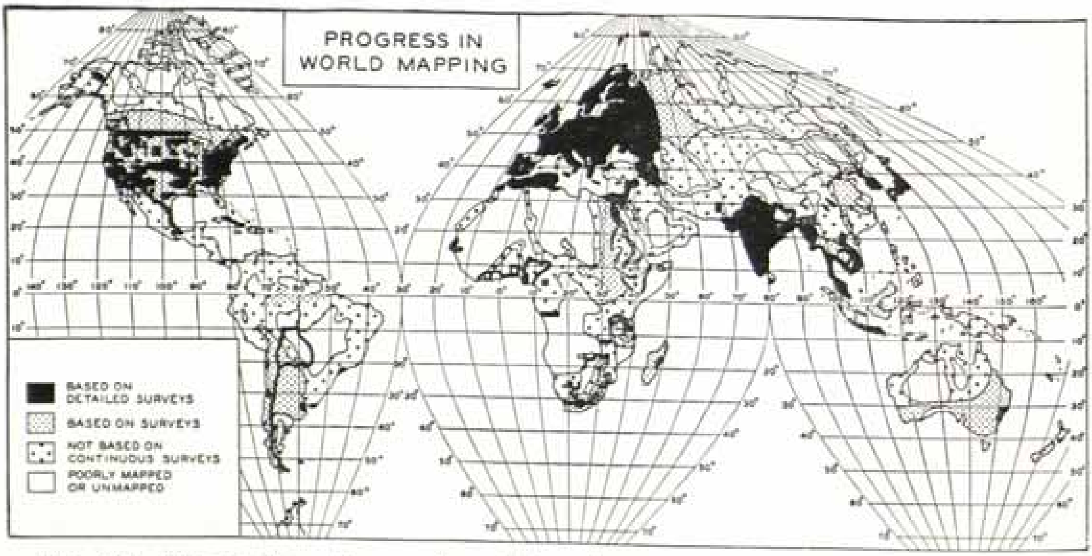


FIG. 410. This map shows the areas for which excellent, detailed maps are available; those mapped in less detail, but with published maps based on continuous surveys; those areas for which maps not based on continuous surveys have been made; and those either very poorly mapped or unmapped at present.

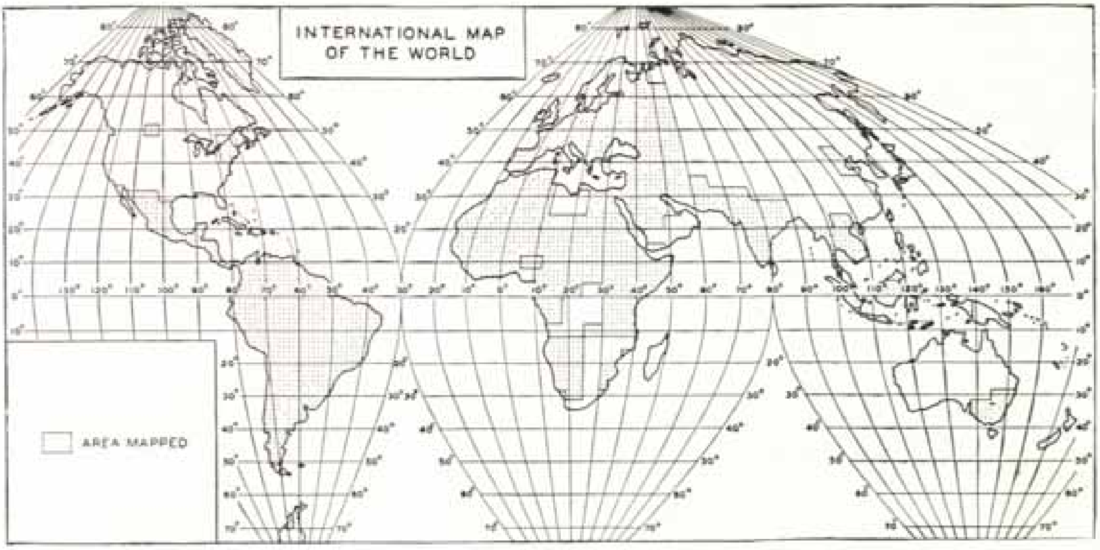


FIG. 411. This map shows the land area for which sheets of the International Map of the World, drawn on a modified conic projection, are available.

the Moslems were crude and limited in number. Thus the effects of cartographic developments in both the Far East and the Moslem world on present-day mapping have been of slight if any importance. Since the sixteenth century, indeed, Oriental mapping has been dominated by Occidental influence.

Modern Mapping and Modern Maps. Since the middle of the nineteenth century, Germany has been the major center of cartographic work; during the eighteenth century, it was France; still earlier, it was the Netherlands. Today we have large-scale, detailed maps for a large fraction of the earth's surface. Such maps are available for Germany, France, the British Isles, and other countries of western Europe. Though less progress has been made in mapping Asia, there are excellent maps available for both Japan and India. Of the other continents, portions are well mapped; of other parts, good maps are lacking, but this deficiency is being remedied rapidly. For our own country, detailed maps, prepared by the United States Geological Survey, are now available for about 50 per cent of the total area, with many new sheets being issued each year, so that in the not distant future we shall have similar large-scale maps for the balance of the United States.

The International Map of the World. A project, under way and partly completed, is the "International Map of the World," on a uniform scale of 1:1,000,000. This world map will consist of approximately 1500 sheets, excluding the oceans. Of these, about 25 per cent have been published. Sheets are now available for Latin America; most of Europe, Africa, and southern Asia; and parts of North America, Australia, and eastern Asia. When all are published, we shall have, for the first time in history, a map of the world on a uniform and large scale. Since this map is compiled from existing maps, however, different sheets must vary considerably in reliability, and reliability sometimes varies as well within the area covered by a single sheet. Despite this limitation, the sheets of the International Map of the World represent a major cartographic contribution.

QUESTIONS AND EXERCISES

1. What is the approximate date of the first map of which we have any record? In what respects does it differ from maps of the present date?
2. What is our basis for belief that primitive populations of the distant past often made and used maps?

3. Report on the polar explorations of Ross and Parry and those of Captain Cook in the Pacific. At what dates were these made and what areas were visited?
4. In what respects did the parallels and meridians of Eratosthenes' map of the world differ from those of maps of the present day?
5. By what name were early geographies known? Why was this an appropriate name at that time?
6. In view of the dimensions of the inhabited world as known to Ptolemy, why was it logical to measure longitude or length in an east-west direction and latitude or width in a north-south direction?
7. Why were the early maps of the Western world so inaccurate? What is a chronometer? How would it be useful in determining longitude?
8. How do "portolano charts" or maps differ from most maps as we know them today?
9. About what time did mapping develop in the Far East? What was the effect of Far Eastern and Moslem cartography on mapping in the Western world?
10. Which of the continents are mapped most adequately? Why?
11. What fraction of the state in which you live has been mapped adequately with good topographic maps?
12. What is the International Map of the World? On what scale is it drawn? What are the advantages of having such a map? For what parts of the world are sheets available? Are all sheets equally reliable? Why? Are single sheets equally reliable in all portions? Why?

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Hinks, Arthur R., *Maps and Survey*, Cambridge University Press, The Macmillan Company, New York, 1942.

This reference supplies a brief history of early mapping, a discussion of modern maps, and a survey of maps available at the present date.

Jervis, W. W., *The World in Maps*, Oxford University Press, New York, 1938, Plates 1–24.

These illustrations in colors show representative maps from the fifth century B.C. to the middle of the eighteenth century A.D. They serve to supplement the descriptions in other references.

Raisz, E., *General Cartography*, McGraw-Hill Book Company, Inc., New York, 1938, Chaps. I–IV.

This work on cartography covers the history of mapping from the time of the earliest maps, through the Medieval period, down to the present. All chapters are well illustrated.

Chapter Forty-Two

MAP PROJECTION

Maps and Map Projection. The only true representation of either the entire or any considerable portion of the earth's surface is on a globe; only for small areas is it possible to make satisfactorily accurate representations or maps on a plane. This is because only for such small areas is the departure of a plane from the curved surface of the spheroidal earth so slight as to be negligible. Nevertheless, maps rather than globes are commonly used because of their greater practicability and convenience.

In all, there are four elements commonly shown as accurately as possible on maps. These are: (1) area, (2) direction, (3) distance, and (4) shape. In addition, maps are sometimes made to show the shortest routes of travel, that is, so that straight lines connecting points on such maps represent these routes.

To show area accurately, each square inch of surface on the map must represent the same number of square miles as every other square inch of surface on the same map. To show direction satisfactorily, any straight line on the map, and all lines parallel to it, must be of constant compass direction. To show distances to advantage, a straight line connecting two points on the map must be the line which can be measured to secure the number of miles between them. To show shapes correctly, the proportions of the minor geographical features of both land masses and bodies of water must be preserved. A map with this quality is said to be "conformal."

Since all maps are compromises, it is impossible to show all of these elements on a single map. By devising a proper system of parallels and meridians, however, it is possible to show one of the four effectively and some of the others with relatively slight and unobjectionable error or, if preferable, to show all inaccurately, but most with such small error that the map can be used for many purposes.

From the foregoing consideration, it is apparent that different kinds of maps can be made for the same area, each valuable for specific uses only. Therefore it is important that students of geography, who make use of maps, become familiar with the limitations and uses of the more important types.

Parallels and meridians can be drawn on a globe in their proper relationship, but this is impossible on a flat surface. There are, however, some curved surfaces approximating that of a globe, such as those of cones and cylinders, which can be spread out without stretching or tearing. These are called "developable" surfaces by contrast with the surface of a globe, which cannot be flattened without distortion or separation. By use of such developable surfaces, lines of sight from the center of the globe, or from some other selected point, may be projected to the surface of either a tangent or secant cone or cylinder which, when cut and unrolled so that it is flat, will have a mesh of parallels and meridians on which the outlines of the land masses and bodies of water may be plotted.

Since a framework of parallels and meridians might be obtained by this procedure, using either a plane or a developable surface, it is called a "projection." In practice, however, few if any projections are made in this manner, but by computation, many being so modified that their relationship to any developable surface, even if present, is difficult to detect. Irrespective of derivation, however, a map projection is any systematic or orderly grid or pattern of parallels and meridians on which the earth's surface may be shown, either in part or in its entirety. The appearance of the map and its utility will be deter-

mined by this grid, for there are a large number of projections, many of limited value and not in common use.

Though there is no possible classification of projections into mutually exclusive groups, four general types are recognizable:

1. Equal area projections, useful for plotting distribution.

2. Conformal projections, in which the shapes of small areas are preserved on the map.

3. Azimuthal projections, in which the azimuth or direction of every point on the map, as seen from some central point, is the same as the corresponding azimuth or direction would be on the earth. This would be a very valuable feature if it could be true for all, as well as for the central point on the map, but since this is impossible, the azimuthal feature is generally incidental, except on maps designed for special purposes.

4. Perspective or geometric projections, in which the mesh is or can be derived by direct projection, through lines of sight from some given point, to the surface on which the map is to be drawn. This may be either a plane or a developable surface.

In the description and discussion which follow, grouping of the individual projections is determined by the type of area for which each is used rather than by the class into which it falls. This is largely as a matter of convenience for students, but in part as well because some of the projections may be classified under more than one heading.

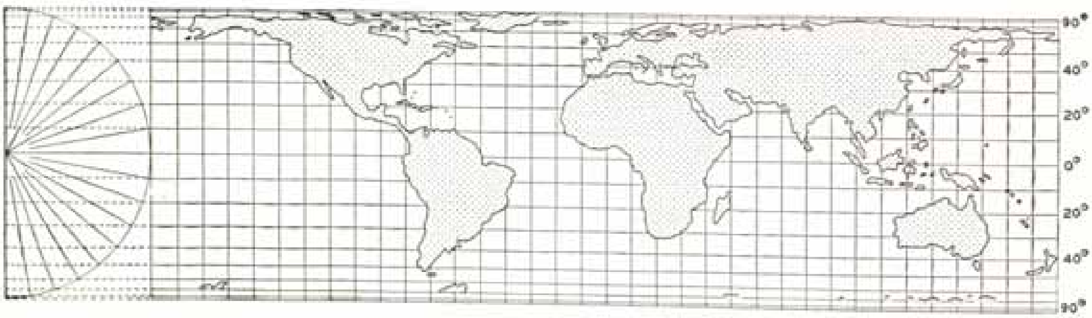

Fig. 412. Cylindrical equal-area projection and its construction.

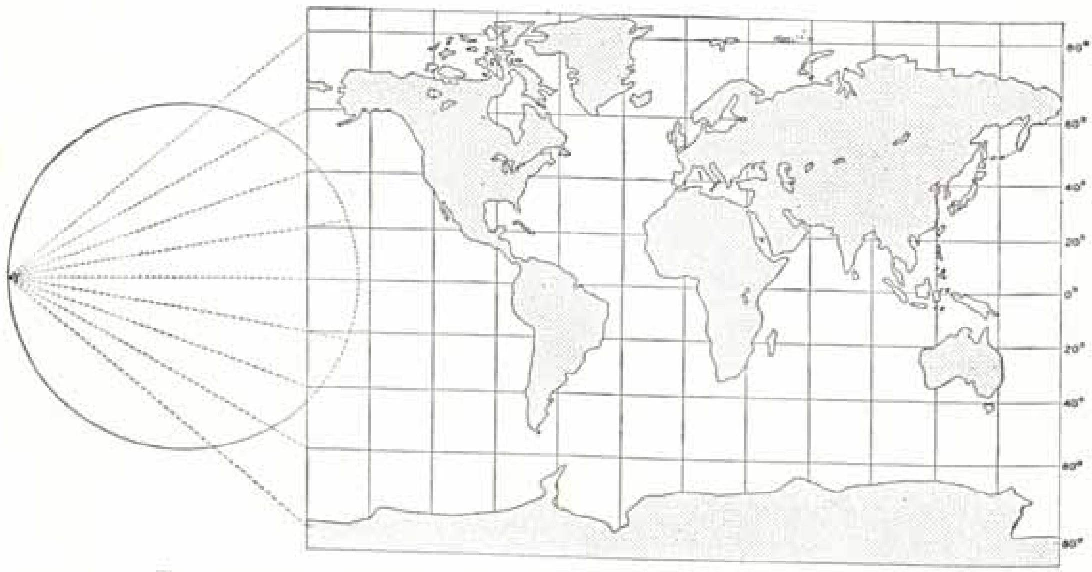

Fig. 413. Gall's stereographic projection and its construction.

Cylindrical Equal-area Projection. As the name suggests, this projection shows area correctly but, as can be seen in the accompanying diagram, Fig. 412, it is likewise a perspective or geometric projection. Meridians are equally spaced on the projection, as on the equator of the globe, to which the cylinder is tangent. The unevenly spaced parallels are located by projection of lines of sight in the planes of the parallels of the globe to the surface of the tangent cylinder. This produces a rectangular mesh with great east-west distortion in polar areas, but with fairly good representation of shapes near the equator, where the surfaces of the globe and the cylinder more nearly coincide. Because of the peculiar shapes of the land masses, this projection is used but little.

Gall's Stereographic Projection. This perspective projection differs from the preceding one in that the lines of sight, which determine the location of the parallels, are projected from one end of the diameter of the sphere, as shown in Fig. 413, to the surface of a cylinder which cuts the globe 45° North and South latitude respectively, midway between the equator and the poles. This produces some compression of equatorial areas but, to compensate, it reduces polar distortion and, near either 45° North or South, the error is slight, which makes it possible to show middle latitudes effectively. For this reason, the projection is rather widely used by Europeans.

Mercator's Projection. The Mercator projection, devised in 1569, is the most important of the cylindrical projections. In it, the cylinder, on the surface of which the map is drawn, is conceived to be tangent at the equator. Therefore the meridians, which are all vertical lines, are spaced equally, with spacing true to scale at the equator. Spacing of the parallels is variable, being so adjusted that, for small areas, the relation between east-west and north-south distances is the same as on the globe, thus producing conformality in limited areas. This spacing of the parallels cannot be obtained by construction but is secured by computation. Since the parallel of 60° is only one-half the length of the equator on the globe, but of equal length on the projection, this preservation of relationships between east-west and

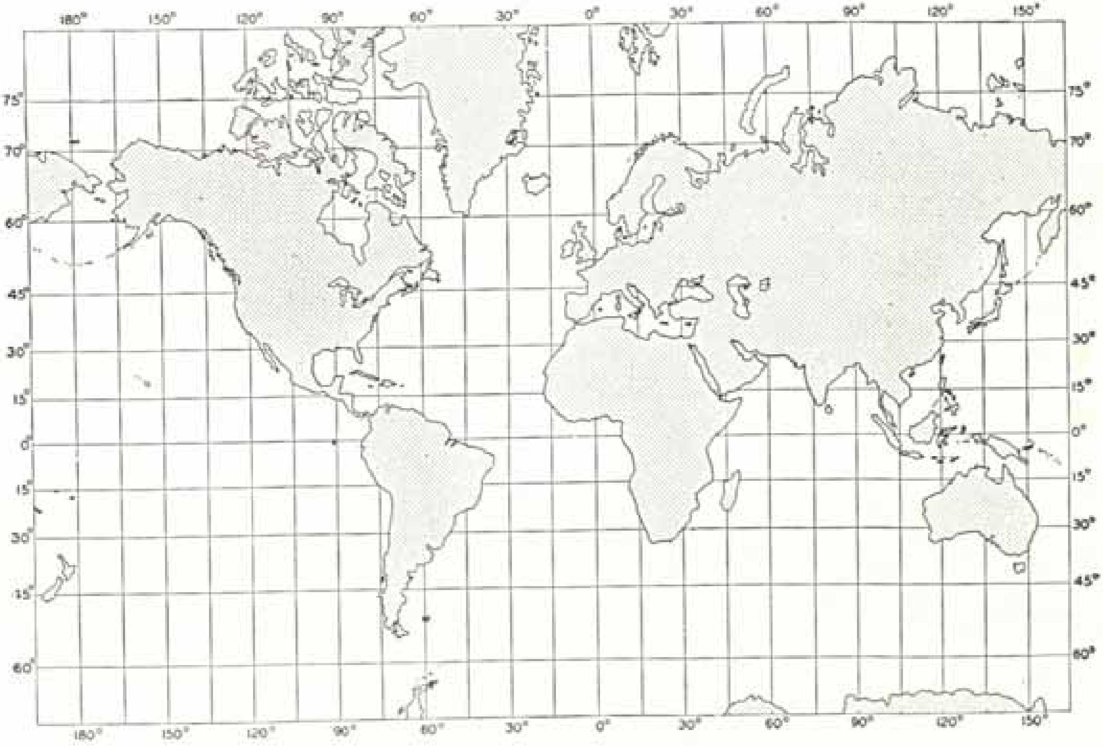

Fig. 414. Mercator's projection.

north-south distances produces a fourfold exaggeration of area at 60° of latitude; at 80° of latitude, it is thirty-sixfold; and, at still higher latitudes, even greater. Since the poles would be represented by straight lines at infinity, this map seldom extends beyond 80° of latitude and, even with such a limitation, South America, which is actually eight times the size of Greenland, appears to be smaller on the map.

This is the only projection which shows all compass directions by straight lines. Therefore it is used for mariner's charts and in mapping by the United States Coast and Geodetic Survey. When used by mariners, the great-circle route, which is generally one of continuously changing compass direction, is plotted as a series of short, straight lines of constant compass direction or "loxodromes" and, in sailing, compass direction is followed along each of these short paths. Ordinary map scales cannot be used on the Mercator projection. Therefore nautical charts have no such scales, but degrees of latitude and longitude are shown, which permits approximate scaling of distance, since 1 minute of latitude equals 1 nautical mile, the determined value of which varies slightly from country to country. (See Chap. XLIII.)

Most commercial maps of the world are drawn on this projection, but though they present the entire surface of the earth without subdivision, as well as permit repetition of parts by east and west extension of the mesh, their general use is unfortunate. This is because they tend to create erroneous impressions as to the comparative areal extent of land masses and oceans and hence are unsuitable for showing distribution, for which use they are frequently employed. When used for its proper purpose, however, the Mercator is one of the most valuable of the projections.

Homolographic Projection. This projection, sometimes known as the "Mollweide" and the "Babinet's equal-area projection," was devised by Karl Mollweide in 1805. It is used extensively in Europe for world maps for, if that continent is given a central location on the mesh of parallels and meridians, the other land masses are distributed effectively. Because of distortion of peripheral areas, it is not so popular in the United States.

In this projection, the equator, divided true to scale, is twice the length of the central meridian, which is a straight line. All other meridians, except those of 90 degrees on either side of the principal meridian, which together form a circle; and the bounding meridians, which describe an ellipse, are elliptical arcs, equally spaced along the straight, horizontal parallels. Parallels are so spaced that the belt between any two represents an area comparable to the corresponding area on the globe, hence area is shown correctly. Scale

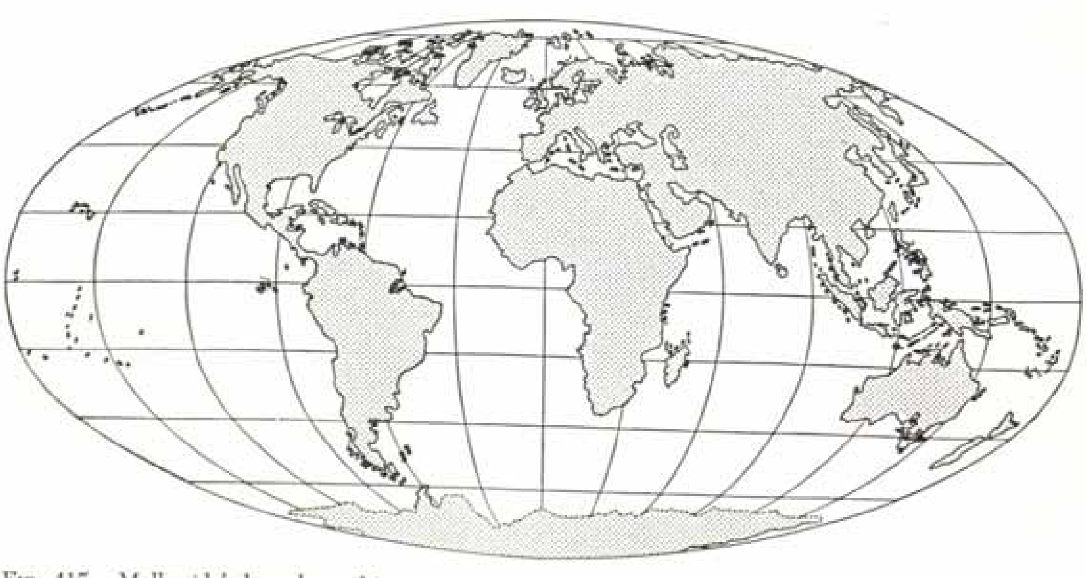

FIG. 415. Mollweide's homolographic projection.

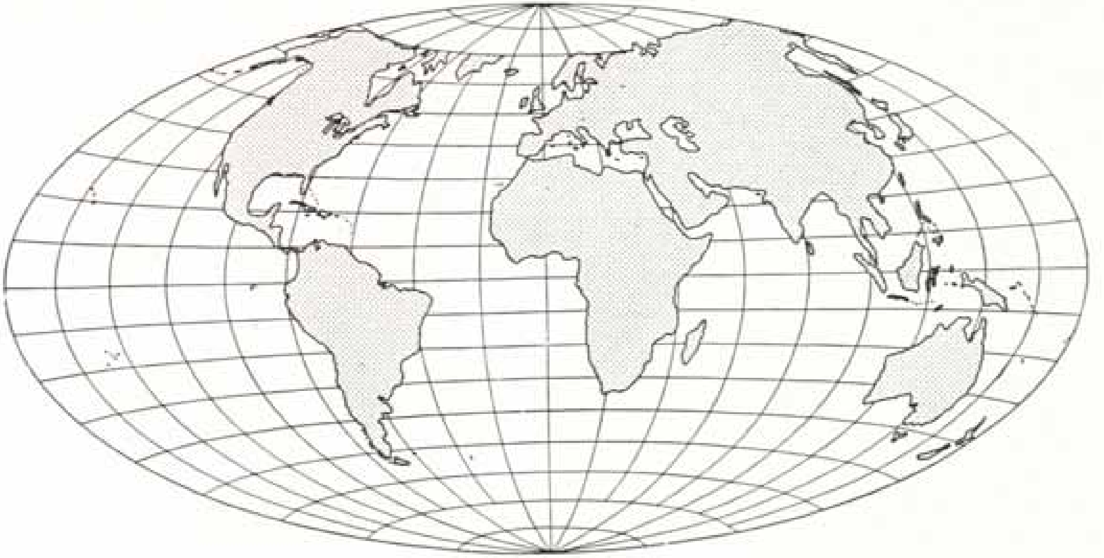

FIG. 416. Aithoff's projection.

is true only on the equator, being exaggerated along the other parallels and somewhat reduced along the central meridian in high latitudes. Within the limitations as stated, this is a rather satisfactory projection for mapping the entire surface of the earth or even the hemispheres.

Aithoff's Projection. This is similar to the Mollweide equal-area projection in that the major axis of the bounding ellipse is twice the length of the minor axis, the principal meridian. However, the curvature of the parallels reduces both polar and marginal distortion to the east and west. Its equal-area characteristic makes it valuable for mapping distribution, more than offsetting the disadvantages resulting from the fact that it is not conformal and that shapes are distorted.

Interrupted Homolosine Projection. This projection is a combination of the homolographic and sinusoidal: sinusoidal between 40° North and South; homolographic in the higher latitudes. It may be interrupted in either the oceans or the land masses, dependent on which of the two it is

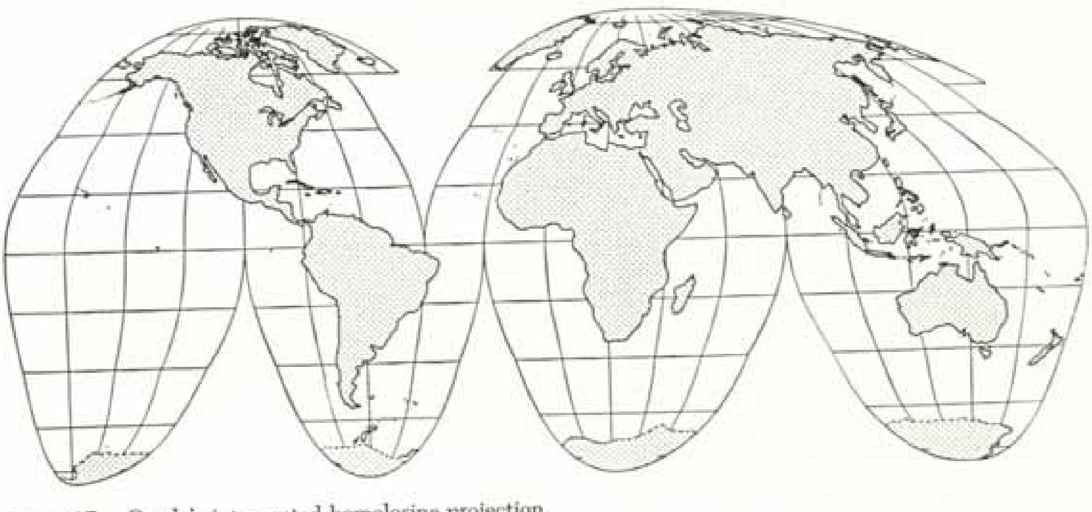

FIG. 417. Goode's interrupted homolosine projection.

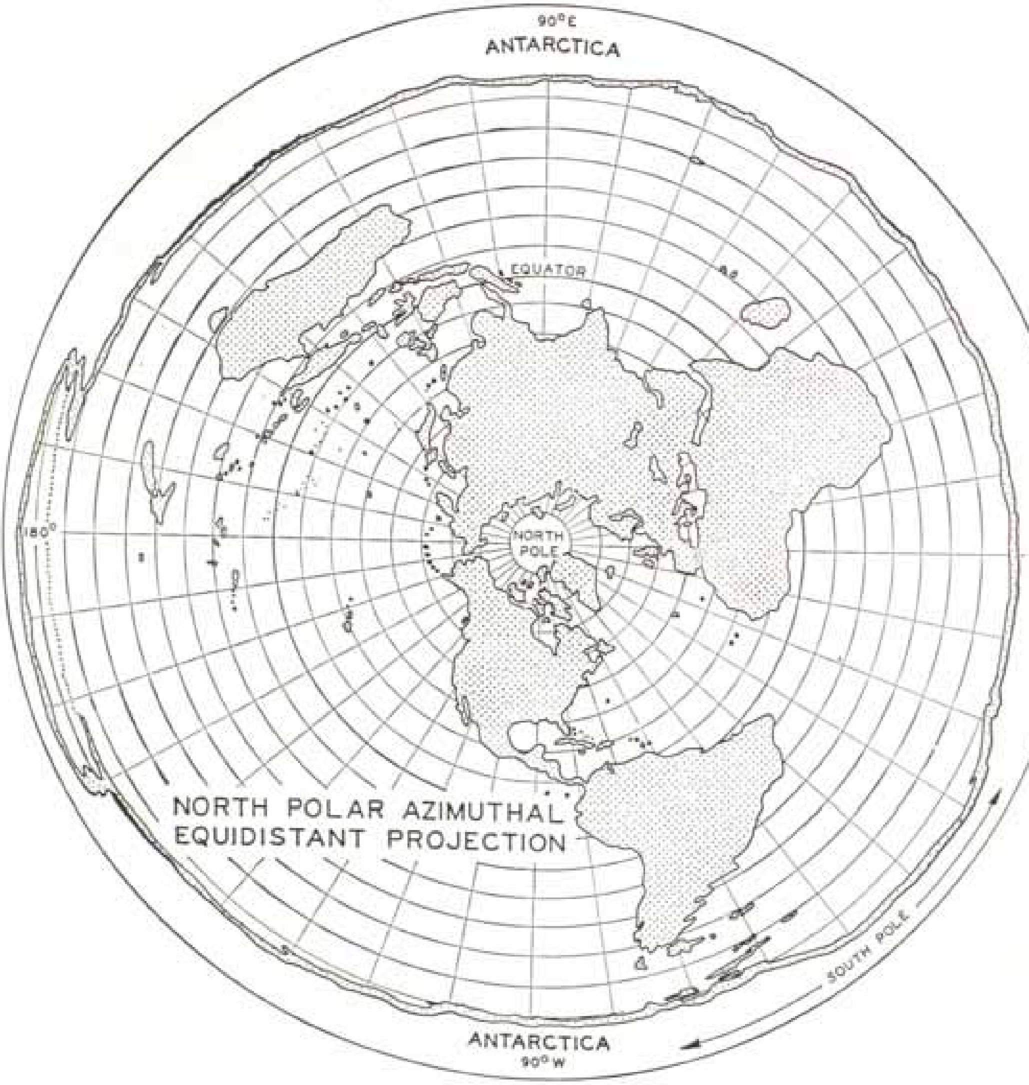

FIG. 418. North Polar azimuthal equidistant projection.

desirable to show with continuity. This interruption makes it possible to give each continent a mid-meridian, thus affording the best shapes it is possible to secure with the two projections which are combined. Derived as it is from two equal-area projections, it shows area correctly and likewise shares in the advantages of the horizontal parallels of the parent projections. It is not, strictly speaking, a new projection, but only a rearrangement of two which have been in use for more than a century. However, it serves a useful purpose and is very good for showing distribution, though the discontinuity of the map interferes with use for certain purposes.

Azimuthal Equidistant Projection. On this projection, straight lines radiating from the center of the map represent great circles, and distances along them are true to scale. It is, however, impossible to construct a map which will show all distances correctly because of the inevitable distortion on all flat maps, but this projection permits determination of distances correctly from one point, the center of the map. Such a map is useful in aeronautics, radio, seismology, and for

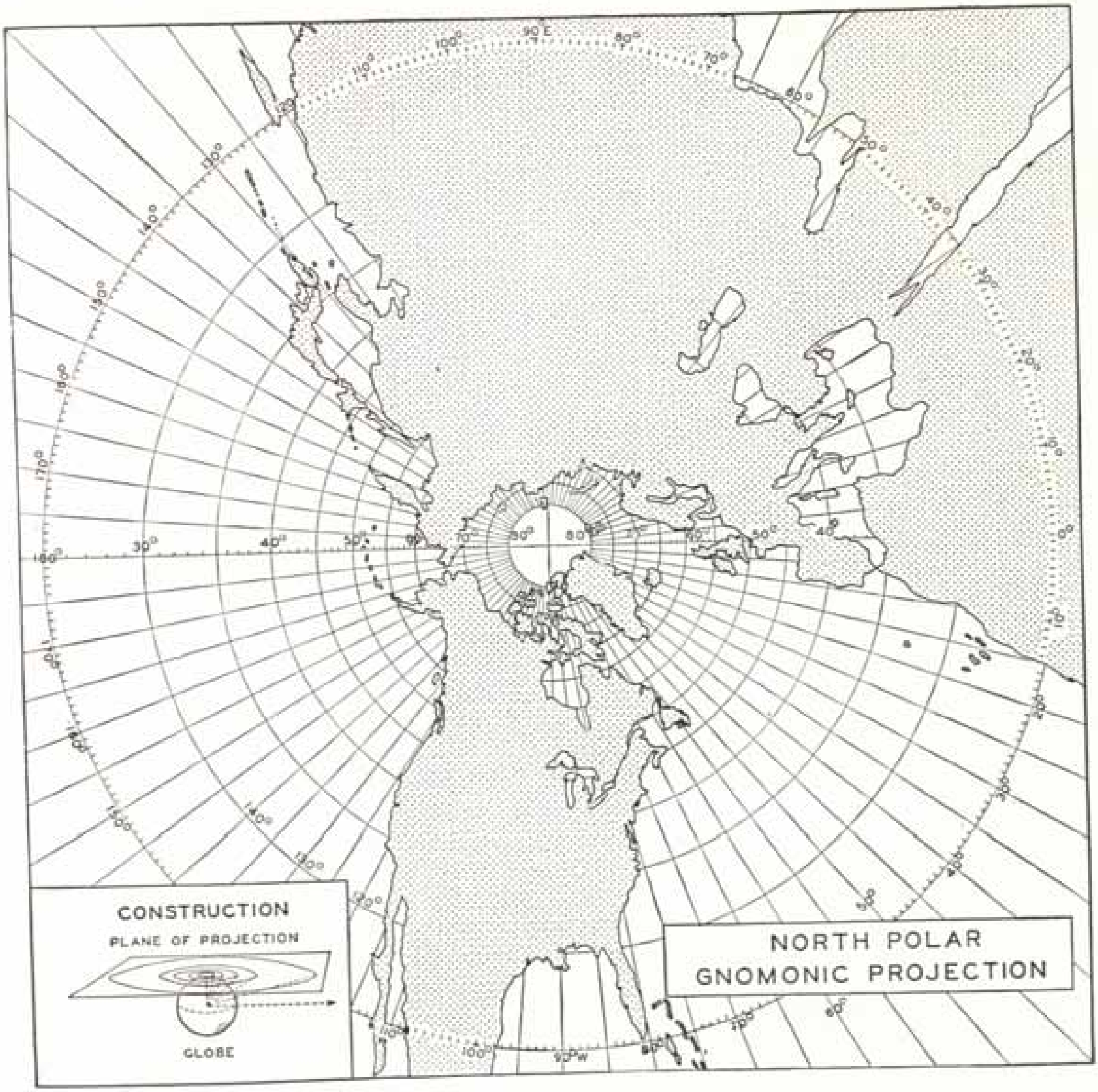

FIG. 419. North Polar gnomonic projection.

other purposes. It suffers from the handicap that a separate map is necessary for each center from which it is desired to scale distances. Though ordinarily made for more limited areas, it is possible to construct such a map for the entire globe. When this is done, both areas and shapes are badly distorted, as shown in Fig. 418.

Gnomonic or Central Projection. This results from the projection of lines in sight from the center of the sphere upon a tangent plane. In the polar case shown in Fig. 419 the common center of the circles representing the parallels is the North Pole, and their equally spaced radii are meridians. Scale change is so rapid that great distortion is introduced in the marginal portions if the map is extended and, obviously, a complete hemisphere cannot be represented. In Fig. 419, the outermost parallel is that of 25° North latitude.

This projection possesses the advantage that a straight line connecting any two points on the map represents a great-circle route, or the shortest route of travel between them. Used in connection with the Mercator chart, this projection

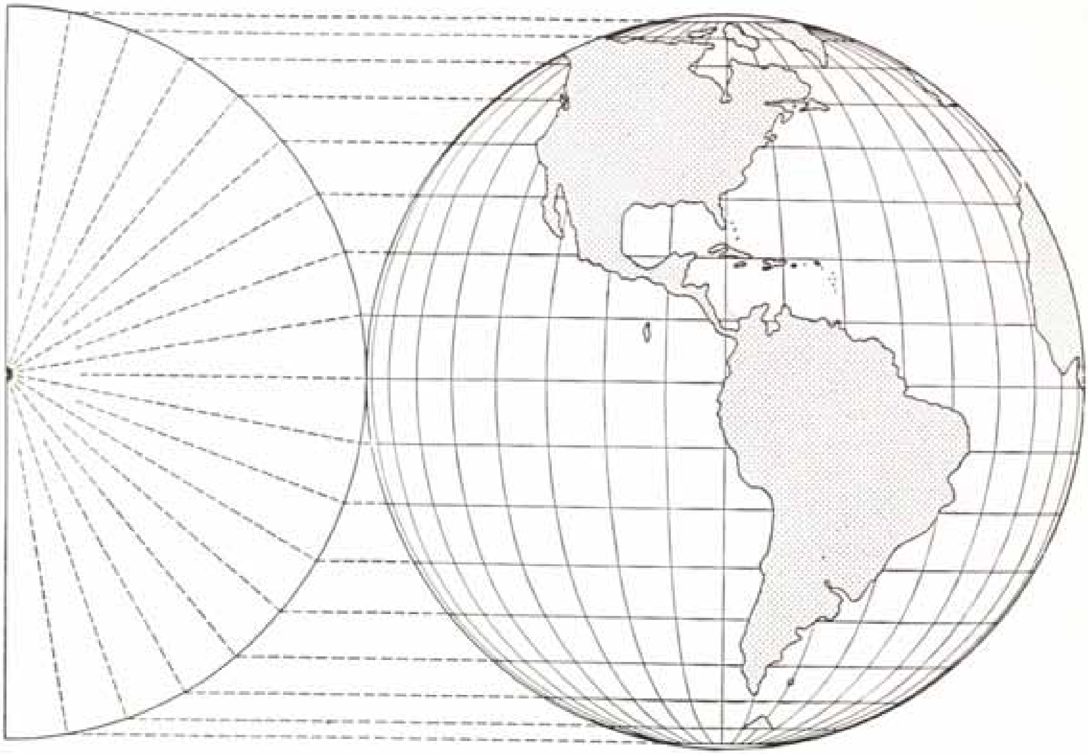

FIG. 420. Orthographic projection and its construction.

has great practical value, for it affords a source from which great-circle routes may be plotted on the Mercator chart as a series of short, broken straight lines, which will fix the compass route. Many charts have been made on the gnomonic projection so that various great-circle routes may be used in part only, if interruption of one is necessitated by obstacles to navigation.

Orthographic Projection. In the grid of the vertical case of this projection, the parallels are horizontal lines; the meridians, except for the straight central and the bounding meridians, which together form a circle, are arcs of ellipses. It is obtained by projection on a perpendicular plane, with the eye at an infinite distance, as shown in Fig. 420. In this particular case, the map extends from pole to pole, though the oblique cases, with a different pattern of parallels and meridians, are met with more commonly. (See Fig. 248 and the end papers in your text.) Because of the impression of sphericity it conveys, various cases of this projection are used frequently, though the map produced is neither equal-area nor conformal. Some of the recent use of this projection has been peculiarly unfortunate because it has been so misleading.

Other projections used for mapping the hemispheres, which likewise create the impression of sphericity, are the globular and the stereographic. In the latter, lines of sight are projected from the end of the diameter of the sphere opposite the plane of the grid; in the former, from some distance beyond the end of the diameter. Both of these projections have meshes with curved parallels and meridians.

Lambert Equal-area Azimuthal Projection. Though this projection, designed by J. H. Lambert in 1772, does not properly belong in the perspective class, it can be constructed graphically as shown in Fig. 422, when the pole is at the center, in which case the radii of the circles which represent the parallels are the chord distances from the parallels to the pole. Meridians are drawn as equally spaced radiating straight lines. This makes a good projection for polar areas; the equatorial case is often used for the hemispheres; the oblique for the continents. Though these last two are more difficult to con-

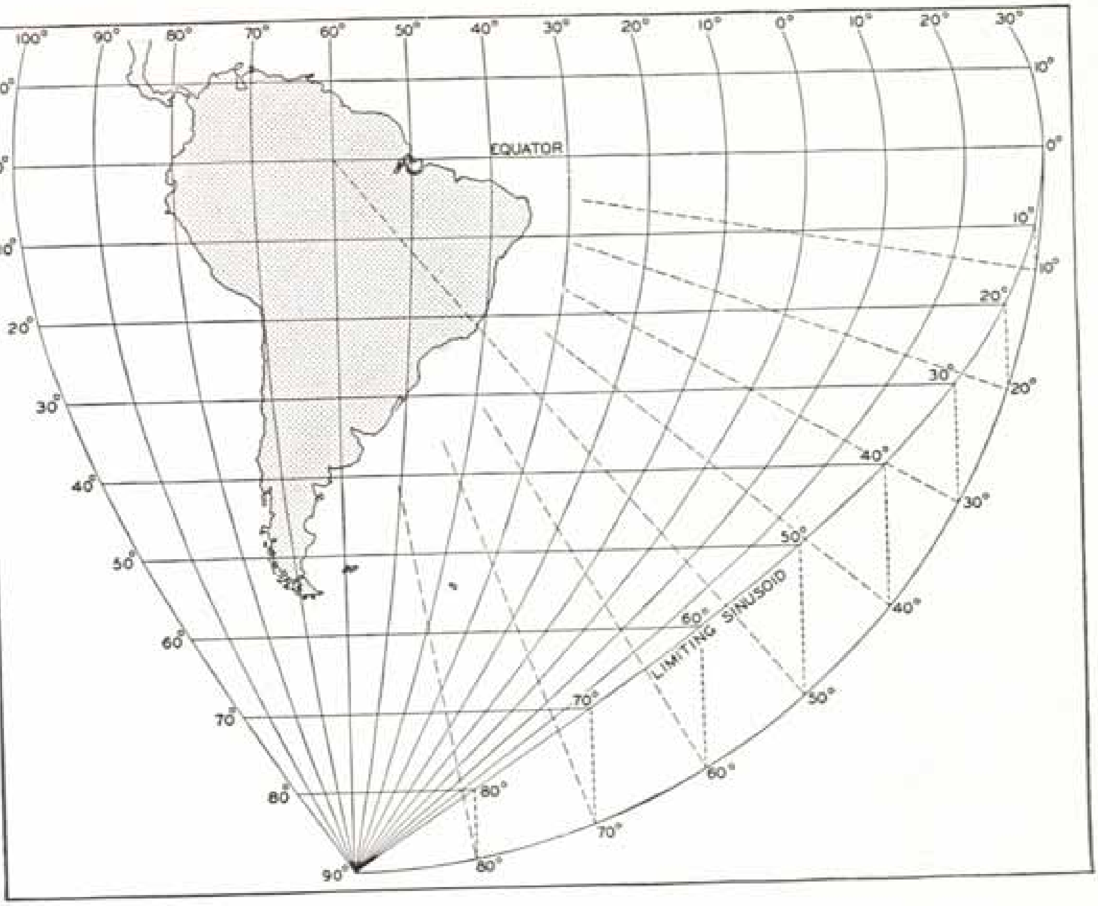

FIG. 421. Sinusoidal projection and its construction.

struct than the polar case, prepared tables which are available reduce this handicap considerably. Because of the small-scale error, this is a valuable projection.

Sinusoidal Projection. This projection was employed as early as 1606 in the Mercator atlases, but without a name. Later, it was named the "Sanson-Flamsteed" projection. It is also sometimes called the "sinusoidal projection," because the meridians are sine curves. This is a very useful projection for mapping continents, particularly Africa and South America, and by interruption of the oceans it may be extended to map the entire surface of the earth. This, in fact, is one of the two projections used in the interrupted homolosine projection described earlier. It is valuable because it shows area correctly; distances are correct on all parallels and the mid-meridian; and shapes of the land masses are good. In addition, it makes studies of comparative latitude simple, for the parallels are horizontal lines. Therefore it makes an excellent base for mapping population densities, natural resources, and other facts, even for the entire world. Many such world maps are scattered through your text.

Conic Projections. In these, the map is drawn on a sector of a circle, a portion of the unrolled surface of a cone. The magnitude of the angle at the center of the sector will vary with the longitudinal extent of the area mapped and other conditions imposed by the projection.

Simple Conic Projection on a Tangent Cone. In the simple conic projection, the grid is plotted on the surface of a tangent cone as shown in Fig. 423. Parallels are concentric circles and the meridians are equally spaced straight lines. Because such a method of construction would produce uneven spacing of the parallels, a correction

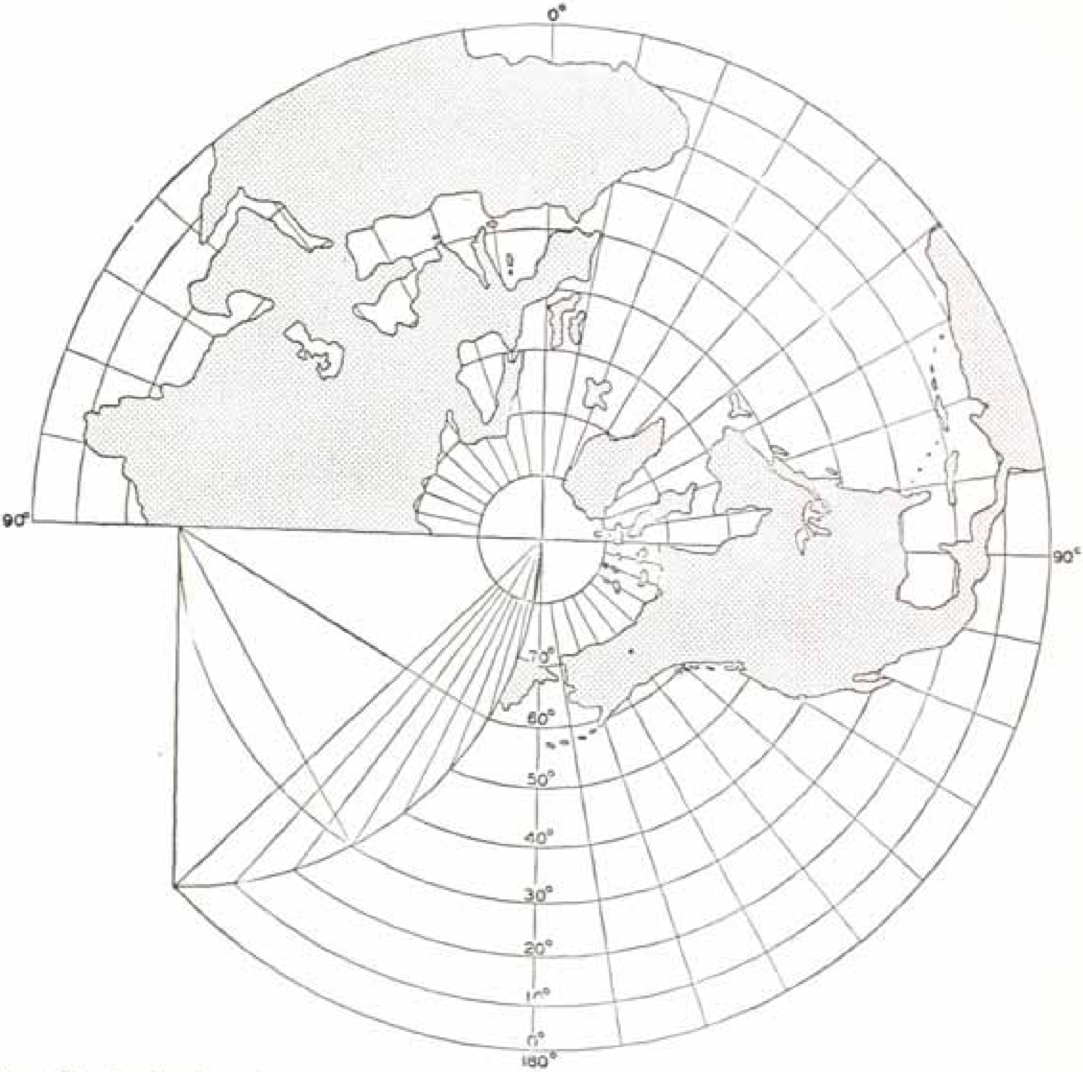

FIG. 422. Lambert's equal-area azimuthal polar projection and its construction.

is applied so that they are spaced evenly at their true distances. Therefore, in practice, the elements of this projection are expressed mathematically rather than derived by construction.

Conic Projection on a Secant Cone. By use of two standard parallels and a secant cone, it is possible to produce either a conformal conic projection or one which shows area correctly. Which one of the two is preferable for a given use depends on whether conformality or equal area is the more important property. In the past, it is probable that the latter was considered more desirable for most uses, but of late, conformal conic projections have enjoyed a considerable degree of popularity and have been widely used by the Army and in air navigation. They are likewise used by the United States Weather Bureau. (See Fig. 456.)

Polyconic Projection. The basic idea of the polyconic projection is the mapping of narrow east-west belts of the area to be shown on a series of cones, each tangent along a parallel in the middle of the narrow north-south belt to be represented. In practice, however, the projection as used is somewhat modified.

In this projection, the central meridian is a

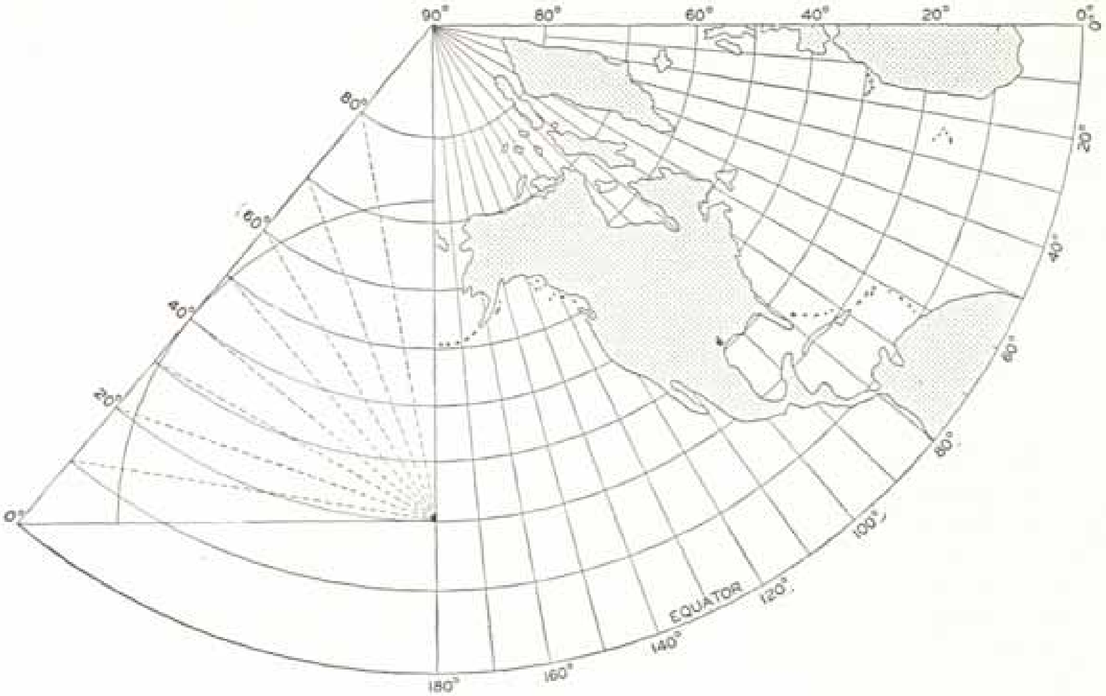

Fig. 423. Conic projection and its construction on a cone tangent at 40° North Latitude, without correction for the uneven spacing of the parallels.

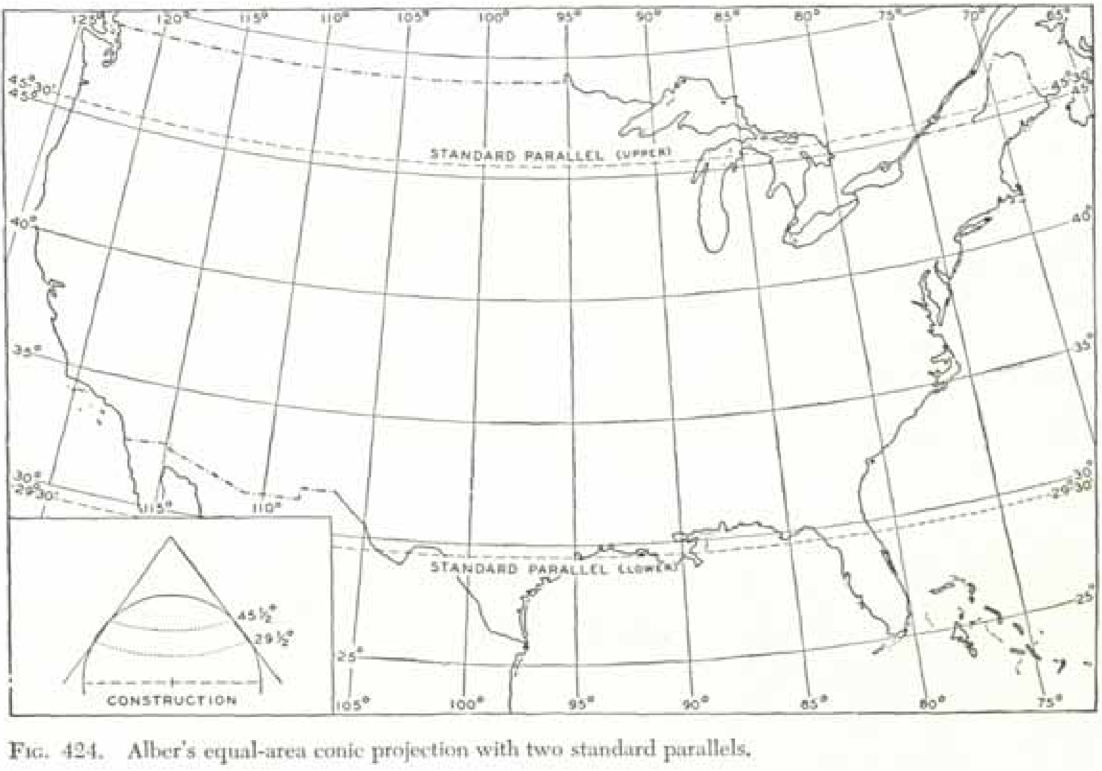

Fig. 424. Alber's equal-area conic projection with two standard parallels.

straight line and the parallels are arcs of circles which are not concentric, though the centers of all lie in the extension of the central meridian as shown in Fig. 425. Along the central meridian, distances are proportional to the true distances on the earth; those between the meridians, all except the center drawn as smooth curves, are likewise proportional to true distances on the earth along the respective parallels of tangency. From Fig. 425 it will be seen that this introduces distortion, except along the principal meridian. Thus the polyconic projection is neither conformal nor equal area, though near the principal meridian the errors are very slight; farther away, the error becomes considerable.

Though not a particularly good projection for mapping the United States, because of its width, it is used for the topographic maps of the United States Geological Survey, in spite of the fact that only those sheets along the central meridian fit accurately. It was likewise used earlier by the United States Coast and Geodetic Survey and is, even now, much used by government agencies, despite the curving meridians and the scale error of its margins. It is therefore, the most common projection employed in mapping the United States, for most such maps are based on government publications. Modified, it is used for the 1:1,000,000 map of the world, for which use the small-scale error is a sufficient advantage to offset the disadvantage that sheets do not fit one another perfectly in all directions.

Other Projections. The projections described do not exhaust the list, but they include all used in the text and most of those of importance and in common use. In addition to those for which illustrations are supplied, two others may be mentioned: the rectangular and the Bonne. The former, used mostly for cities and other small areas, consists of a rectangular mesh, with scales true on the meridians and central parallel only. Though neither conformal nor equal area, its

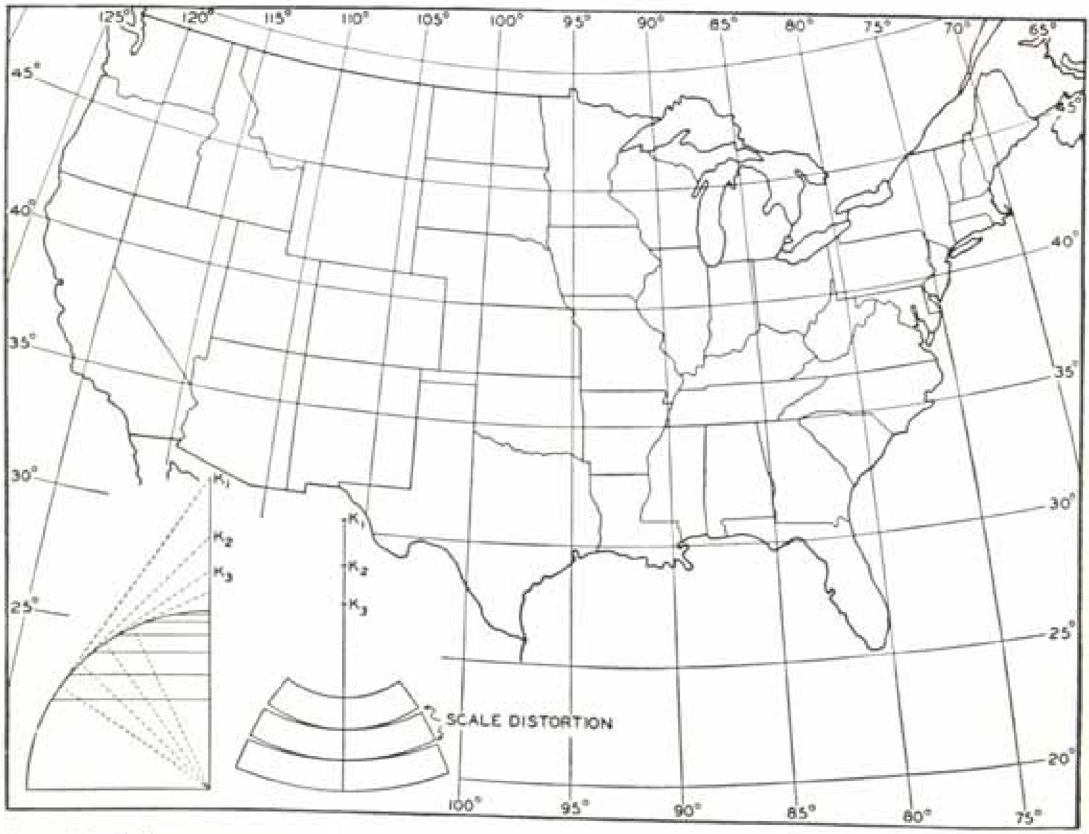

FIG. 425. Polyconic projection for the United States, and diagram to show the error introduced.

simplicity of construction makes it practical, if the area represented is not too extensive. The Bonne projection, designed by the French cartographer of that name who lived during the eighteenth century, has a straight central meridian, a standard parallel derived as in other conic projections, and all other parallels concentric with the principal one. Meridians are curved lines drawn through points which divide the parallels truly. If the standard parallel is the equator, this projection becomes identical with the sinusoidal. The Bonne projection, which is often used for mapping the continents, shows area correctly and shapes accurately along the central meridian. It is also used for topographic maps in small countries such as the Netherlands.

QUESTIONS AND EXERCISES

1. Why is it impossible to represent the earth's surface accurately on a plane? Why are flat maps rather than globes in common use despite this fact?
2. What four elements is it desirable to show as accurately as possible on a map? What is meant by showing area accurately? What is meant by the statement that a map is "conformal"?
3. What is meant by a "projection"? How are projections obtained in practice? What is a "developable" surface? Why are such surfaces useful in making maps?
4. Into what four classes may maps be divided? What are the characteristics of each class?
5. Name the cylindrical projections described in the text. Which one of them shows area correctly? Which one is rather widely used in Europe but not in the United States? Why?
6. Which one of the cylindrical projections described is most widely used in the United States? What advantage does it possess? Why is it a poor projection to use for showing distribution?
7. What are the advantages of the homolographic projection? Describe the pattern of its parallels and meridians. Why is this projection often used in European maps of the world?
8. In what respects does the pattern of parallels and meridians of Aithoff's projection differ from that of the homolographic projection? What advantage does this produce?
9. What projection, much used for world mapping in the United States, is made by combining parts of two projections? What advantages does it possess? From what disadvantage does it suffer?
10. For what use is the equidistant projection devised? Is it possible to determine the distance in miles between any two points on this map? If not, between what points?
11. For what is the gnomonic projection used? Explain how it is used by mariners in connection with the Mercator chart.
12. Name three projections which convey the idea of sphericity, all used in mapping the hemispheres. Which one of the three is used for the maps, the end papers in your text?
13. What projection is commonly used in mapping polar areas? What advantages does it possess for such use?
14. What are the advantages of the Sanson-Flamsteed or the sinusoidal projection? For what continents is it generally used?
15. For what uses have conformal conic projections enjoyed considerable popularity of late years?
16. What projection is most commonly used for mapping the United States? Why? Why is this not a particularly good projection for such use?

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Deetz, C. H., and Adams, O. S., *Elements of Map Projection,* Special Publication No. 68, 5th ed., U. S. Coast and Geodetic Survey, Washington, 1945.

This is a standard publication containing an analysis of the basic elements of map projection, an elementary discussion of various types of projection, many illustrations, and a number of tables. It has enjoyed such popularity, in fact, that several reprintings, as well as a revision, have been necessary to meet the demand.

Johnson, W. E., *Mathematical Geography,* American Book Company, New York, 1907, Chap. X.

This reference contains an elementary discussion of map projection.

Raisz, E., *General Cartography,* McGraw-Hill Book Company, Inc., New York, 1938, Chaps. VI, VII, VIII.

This is one of the more recent texts in cartography, covering all aspects of the field. The chapters cited are concerned with map projection.

Chapter Forty-Three

THE EARTH'S DIMENSIONS AND MATHEMATICAL LOCATION

Shape and Size of the Earth. The earth is spheroidal in shape, flattened, but not equally, at the two poles, the opposite ends of the axis of rotation. There are also other departures from sphericity. For example, the equator is not a perfect circle, which introduces minor differences in the curvature of the meridians, circles drawn through the poles. Because of these irregularities of shape, the mathematical center of the earth is not located exactly in the plane of the equator. Thus, of the regular geometric solids, the one which most nearly represents the earth is an oblate spheroid though, more accurately, its form, disregarding minor surface irregularities such as mountains and valleys, must be described as that of a geoid, or the spheroidal mathematical form which most closely coincides with the actual shape of the earth.

Earth Measurements. Many measurements have been made from the time of Eratosthenes or earlier down to the present to determine the exact dimensions of the spheroid, for such information

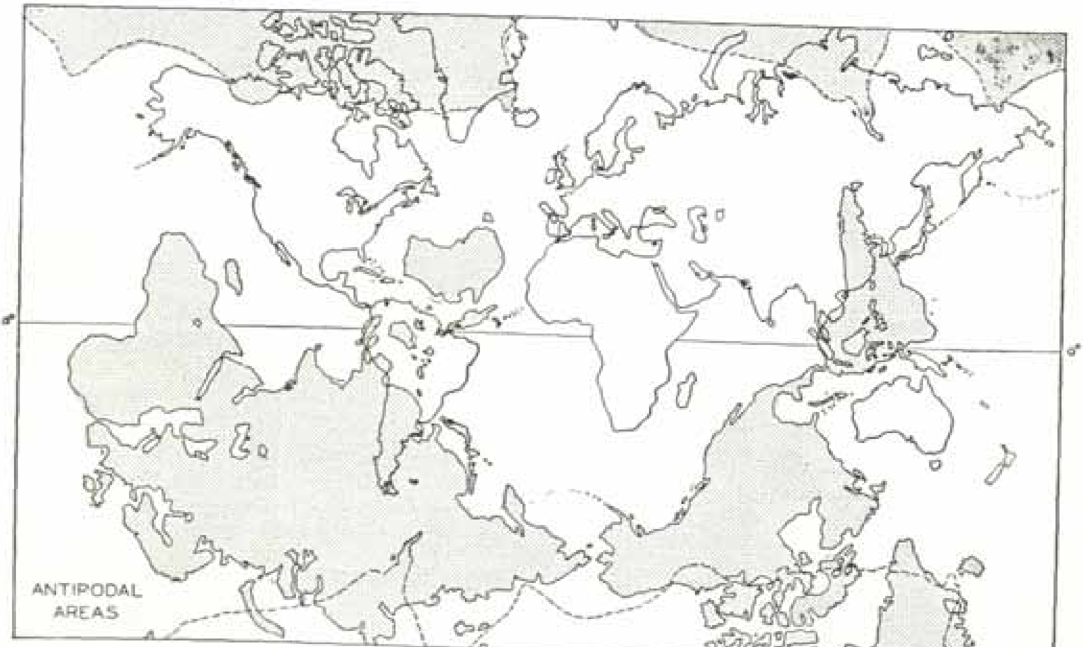


FIG. 426. Map of antipodal areas, or those opposite one another on the earth. Thus the map shows that Australia is on the opposite side of the earth from the mid-Atlantic; that the southern tip of Africa occupies a similar position with reference to the mid-Pacific; and that the southern tip of South America has an antipodal location with reference to central Asia.

is of value to astronomers, surveyors, and many others. At present, therefore, we know the size of the earth to within very narrow limits, though additional measurement will continue for many years, both for purposes of verification and to determine minor departures from the general shape. Some of the estimates of the size of the earth are based on astronomical facts; others on pendulum experiments; and some on careful surveys such as actual measurement of arcs of parallels and meridians. From work done in the past it is now known that the equatorial diameter of the earth is approximately 7926 miles and the polar diameter 27 miles less, or about 7899 miles. More accurately, according to the 1909 computations of Hayford, the equatorial diameter is 7926.68; the polar diameter, 7899.98; and the difference between them, 26.70 miles. The flattening at the poles, indicated by the shorter diameter, is assumed to have resulted from rotation, particularly when the earth, in its earlier stages of development, was more plastic than at present. Though these determined dimensions may later be subject to some correction, it is believed that the possible error in each is not great, for the results of several different computations made between 1841 and the present differ but slightly more than a mile, and those made recently, by less than half that much. The value of a geographical or nautical mile is based on these measurements which, differing somewhat, causes the value assigned to this unit of measurement to vary slightly in different countries. Thus our nautical mile equals 6080.20 feet; that of Great Britain, the Admiralty miles, is 6080 feet; that of France and Germany is about 4 feet shorter, or 6076 feet.

Latitude and Longitude. Latitude, in its ordinary meaning signifying "width," is measured north and south because the world, as known and mapped in earlier times, was longer east and west than north and south. Latitude is therefore measured from the equator along a meridian, the number of degrees, minutes, and seconds in

Latitude	*Value of a Degree of Longitude in Miles*	*Value of a Degree of Latitude in Miles*	*Latitude*	*Value of a Degree of Longitude in Miles*	*Value of a Degree of Latitude in Miles*	*Latitude*	*Value of a Degree of Longitude in Miles*	*Value of a Degree of Latitude in Miles*
0°	69.171	68.704	31°	59.345	68.890	61°	33.622	69.241
1	69.162	68.704	32	58.717	68.901	62	32.560	69.251
2	69.130	68.705	33	58.071	68.912	63	31.488	69.261
3	69.078	68.706	34	57.407	68.923	64	30.406	69.271
4	69.005	68.708	35	56.726	68.935	65	29.315	69.281
5	68.911	68.710	36	56.027	68.946	66	28.215	69.290
6	68.796	68.712	37	55.311	68.958	67	27.106	69.299
7	68.660	68.715	38	54.578	68.969	68	25.988	69.308
8	68.503	68.718	39	53.829	68.981	69	24.862	69.316
9	68.326	68.721	40	53.063	68.993	70	23.729	69.324
10	68.128	68.725	41	52.281	69.006	71	22.589	69.332
11	67.909	68.730	42	51.483	69.018	72	21.441	69.340
12	67.670	68.734	43	50.669	69.030	73	20.287	69.347
13	67.411	68.739	44	49.840	69.042	74	19.126	69.354
14	67.131	68.744	45	48.995	69.054	75	17.960	69.360
15	66.830	68.751	46	48.135	69.066	76	16.788	69.366
16	66.510	68.757	47	47.261	69.079	77	15.611	69.372
17	66.169	68.764	48	46.372	69.091	78	14.428	69.377
18	65.808	68.771	49	45.469	69.103	79	13.242	69.382
19	65.427	68.778	50	44.552	69.115	80	12.051	69.386
20	65.026	68.786	51	43.621	69.127	81	10.857	69.390
21	64.606	68.794	52	42.676	69.139	82	9.659	69.394
22	64.166	68.802	53	41.719	69.151	83	8.458	69.397
23	63.706	68.811	54	40.749	69.163	84	7.255	69.400
24	63.227	68.820	55	39.766	69.175	85	6.049	69.402
25	62.729	68.829	56	38.771	69.186	86	4.841	69.404
26	62.212	68.839	57	37.764	69.197	87	3.632	69.405
27	61.676	68.848	58	36.745	69.209	88	2.422	69.407
28	61.121	68.858	59	35.715	69.220	89	1.211	69.407
29	60.548	68.869	60	34.674	69.230	90	0.000	69.407
30	59.956	68.879						

FIG. 427. Diagram to show why the value of a degree of latitude is greater near the poles than in the lower latitudes, with the differences in curvature between the low and high latitudes greatly exaggerated.

the arc of the meridian between the equator and a given place being its latitude. If the earth were a perfect sphere, all meridians would be perfect circles, and 1/360 of each, or 1 degree, would have the same value in miles. Reference to the accompanying table of values of degrees of latitude, however, will show that in reality the value of a degree of latitude is somewhat greater near the poles than at or near the equator. This increase in value in higher latitudes results from the fact that 1/360 of the circle of which the polar part of the meridian is a portion has a greater value than 1/360 of the smaller circle of which the same meridian nearer the equator is a part. This difference in the size of the circles results from the fact that the earth is roughly an oblate spheroid in shape. (See Fig. 427.)

Longitude or "length" is measured east and west because the earlier known world, confined to areas around the Mediterranean, was longer east and west than north and south. It is measured along parallels, or lines drawn parallel to the equator, from a selected meridian known as the "prime" or "principal" meridian, and expressed in degrees and subdivisions of degrees. Thus the longitude of a point on the earth's surface is the number of degrees, minutes, and seconds in the arc of the parallel between that point and the prime meridian. Longitude is commonly reckoned today from the prime meridian which passes through the former site of the Royal Observatory at Greenwich, near London, though other meridians are sometimes used as the starting point for measurement. Thus the French may use that of Paris; the Portuguese, that of Lisbon; and we, that of Washington, D.C. However, unless designated otherwise specifically, when longitude is stated among English-speaking peoples it is understood to be reckoned from Greenwich. The value of a degree of longitude varies within wide limits, as shown by the accompanying table, for the parallels are circles of quite different size. Therefore 1/360 of one, or 1 degree, may be very different from 1/360 of another. The maximum value will be along the equator, which is the largest of these circles, and values will decrease north and south to the poles, where it will become zero.

From these values, as tabulated, it is obvious that the location of a point on the earth's surface may be described within very narrow limits by stating its latitude and longitude. For example, the Time Capsule, containing various items characteristic of our present civilization and buried 50 feet deep under the Westinghouse Building at the New York World's Fair, was located 40° 44′ 34.089″ North latitude and 73° 50′ 43.842″ West longitude, with an error of less than 1 inch, by the United States Coast and Geodetic Survey. Therefore, when it is to be removed and opened for the inspection and benefit of future generations, 5000 years hence, it will be possible to find it without difficulty.

QUESTIONS AND EXERCISES

1. What is the shape and size of the earth? How have these been determined? Within what limits of error do we now know the size of the earth? Of what importance is this knowledge? What is the major departure of the earth from sphericity? How does this departure affect the shapes of the meridians?
2. What is meant by "longitude"? By "latitude"? Why are they measured as they are? From what is each measured? In what units of measure?

3. What is the value in miles of a degree of latitude near the equator? Near the poles? Why the difference?
4. What is the value of a degree of longitude in miles at the equator? At the poles? Why this great variation in value?
5. How accurately is it possible to locate a point on the earth's surface by stating its latitude and longitude in degrees, minutes, and seconds?
6. What is the latitude and longitude of your home town in degrees, minutes, and seconds? What would be the dimension in miles of a quadrangle 1 minute of latitude by 1 minute of longitude in the latitude of your home town? Of a quadrangle 1 second of latitude by 1 second of longitude in your home area?
7. What spot on the earth's surface has an antipodal location with reference to your home town? Why is Australia sometimes referred to as "down under"?
8. What is the value of a nautical mile in feet? Why does it vary slightly in value in different countries? What is the value in feet of the British Admiralty mile?

SELECTED REFERENCES

Johnson, W. E., *Mathematical Geography*, American Book Company, New York, 1907, Chap. II.

This reference affords a discussion of the shape and size of the earth, latitude, longitude, and antipodal areas.

Raisz, E., *General Cartography*, McGraw-Hill Book Company, Inc., New York, 1938, Chap. V.

This chapter deals with the earth's dimensions, parallels, and meridians.

Chapter Forty-Four

MAP SCALES

Map Scales. In its essential aspects, a map is a black and white or colored sketch, somewhat like that drawn by an artist, though different techniques and conventionalized symbols are used in its construction. Like the landscape produced by the artist, it also represents a portion of the earth's surface on a reduced scale. In the picture, the reduction is relatively slight and easily appreciated, but on the map it is so great that some measure or scale to show the proportional relationship of the map to the area it represents becomes desirable.

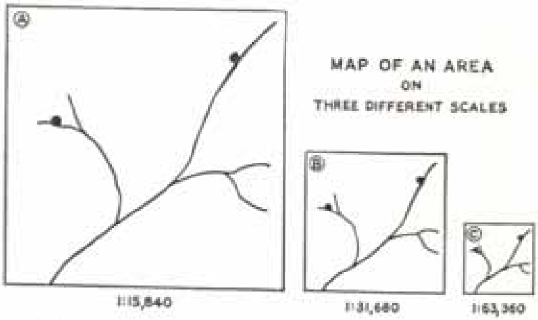


FIG. 428. A series of maps to show the effect of enlargement and reduction on the map scale.

Such scales are expressed in three different forms, sometimes one and sometimes more than one accompanying a given map. These forms are as follows:

1. A ratio scale, which expresses the numerical relation between linear dimensions on the map and the same dimensions on the earth's surface as a ratio or fraction, for example, 1:4,000,000. This indicates that if two points are 1 inch apart on the map, assuming that there is no distortion of distance on the map, they are actually 4,000,000 inches or 63.1313+ miles apart on the earth's surface, that is, the ratio between distances on the map and the earth's surface is 1:4,000,000.

2. An "inch-to-inch" scale, in which the value of an inch on the map is expressed in miles, by use of words, for example, 1 inch to 10 miles. This expression of the scale is often employed on maps for popular use.

3. A graphic scale, in which a line is marked off in divisions which show distances on the map. This is likewise a common method of expressing the scale on maps designed for general use.

The usual ratio scales employed in countries which use the metric system are: 1:100,000, 1:200,000; in the British Empire, 1:63,360, 1:126,720; in the United States, 1:62,500, 1:125,000, and multiples of the second number of the ratio. Direct reading of values from these scales is simplest in the first of the three, where 1 centimeter corresponds to 1 kilometer, when the scale is 1:100,000. If there is no scale stated on a map, one may be secured by remembering that the value of 1 degree of latitude equals approximately 69 miles. The measurement should be made in the center of the map or on a straight meridian, to avoid error.

Scale Change by Map Enlargement or Reduction. When a map is either enlarged or reduced, the scale of miles changes. For example, if the two cities represented by dots on Fig. 428A are 1 inch apart on the map, the actual distance between them is 15,840 inches or ¼ miles, as shown by the ratio scale below. If this map is reduced in size, as shown in Fig. 428B, the distance between the two cities will be only half as great, or ½ inch on the map. However, the two cities are still 15,840 inches, or ¼ mile apart. Therefore ½ inch on this map represents 15,840 inches or ¼ mile, and 1 inch represents 31,680 inches or ½ mile. Therefore the ratio scale is

1:31,680. If the map is again reduced, as shown in Fig. 428C, so that the cities are only ¼ inch apart on the map, the scale will become 1:63,360, or 1 inch equals 1 mile, for there are 63,360 inches in a statute mile. In the case of map enlargement rather than reduction, the scale would undergo a similar change, but in the reverse direction, that is, 1 inch on the map would represent a decreasing number of miles with enlargement.

Since most map reduction or enlargement is by photographic processes, it is desirable to use scales which will change in proportion to the reduction or enlargement in size of the map photographed. The only one of the scales for which this would be true is the linear scale. Therefore this is used in making maps for reproduction, as may be noted by examining the maps in the text.

Inasmuch as most maps are not designed to show distances accurately, and no map shows distances truly in all directions, it is impossible to scale off exact distances between most places on a map. If the area mapped is small, however, the error is not great and, even when it is larger, approximations which are useful may be secured by use of the scale of miles given on the map.

QUESTIONS AND EXERCISES

1. What are the three types of scales of miles used on maps? Which ones are most common on maps designed for general use? Why?
2. What are the common ratio scales employed in countries which use the metric system? In the British Empire? In the United States?
3. If a map with a ratio scale of 1:4,000,000 is reduced in size so that two cities which are 1 inch apart on the original map are only ⅛ inch apart on the reproduction, what will be the ratio scale for the reproduction?
4. Of the three types of scales used on maps, which one is it best to use on maps designed for reproduction? Why?
5. Why is it generally impossible to secure the true distance between two places on a map by use of the scale of miles? What type of map would it be best to use to secure distances correctly? Why is the error in distances less on maps of small areas than on those of maps of larger regions? Even though this is true, is it possible to determine distances between places accurately on most maps?

Chapter Forty-Five

DIRECTION ON MAPS AND COMPASS DECLINATION

Direction on Maps. Directions on the earth's surface are determined with reference to the two geographical poles, which are the ends of the axis of rotation. Thus two points north and south of one another lie along the path of the same meridian and two points east and west of one another along the path of the same parallel.

Compass Declination. The magnetic compass, however, commonly used for determining direction, does not point toward the geographical but the magnetic poles, which are located northwest of Hudson Bay in the Arctic and in South Victoria Land in the Antarctic, within the polar circles but several hundred miles from the geographical poles. Thus there are but few places on the surface of the earth where the compass

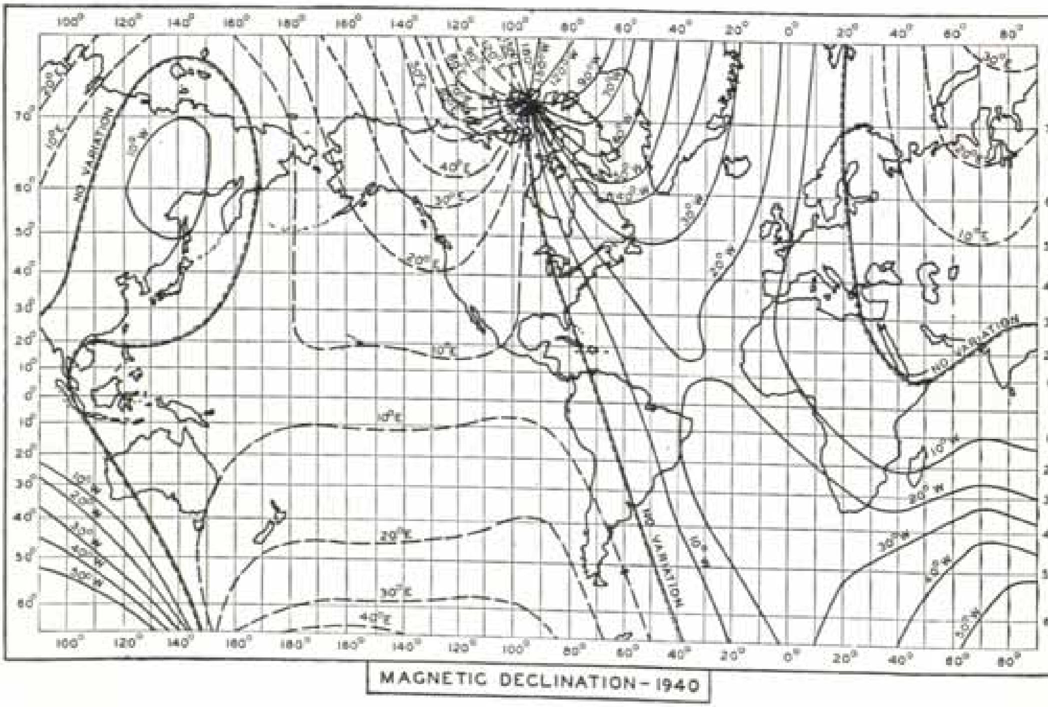


FIG. 429. Chart showing magnetic declination for the world. Along the lines marked O, the agonic lines, the compass needle points due north and south. Along these lines, therefore, no correction of the compass reading is necessary. Elsewhere, however, this is not true for, to the east of the agonic line, the compass needle points to the west of north; west of the agonic line, to the east of north. Departure is equal along the numbered lines trending with the agonic line, the so-called "isogonic lines," or those along which the declination is equal. The amount and direction of this declination is indicated in degrees on each isogonic line. (After the U. S. Coast and Geodetic Survey.)

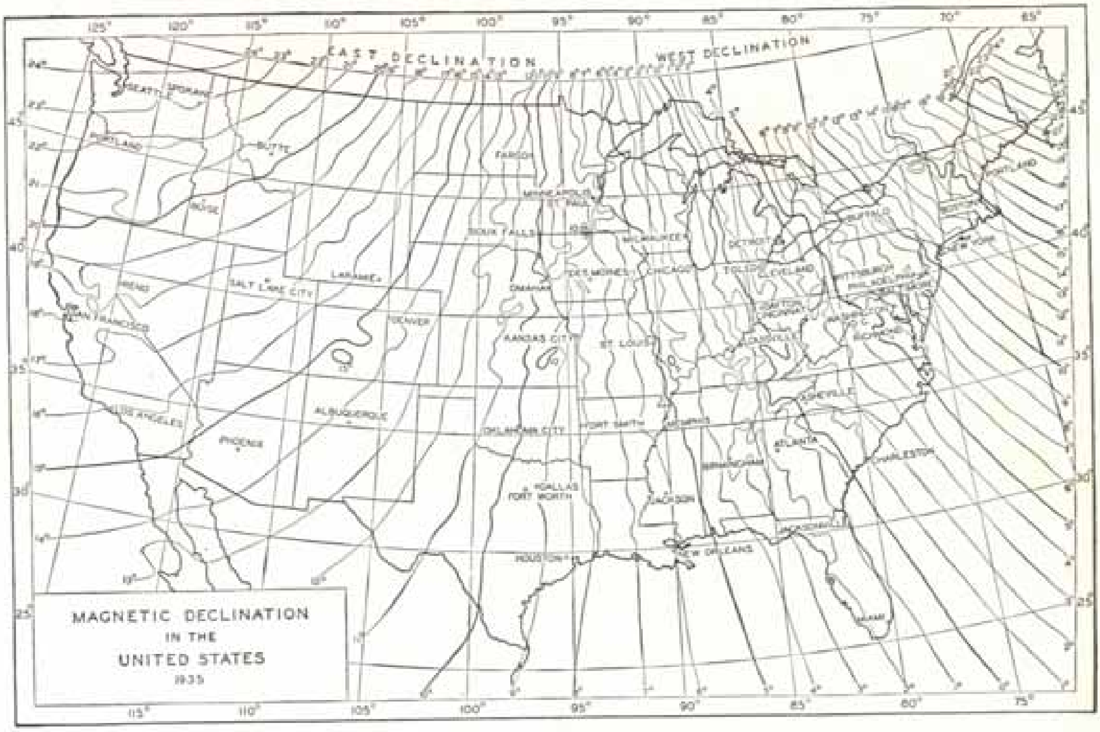


FIG. 430. Chart showing magnetic declination for the United States in 1935. The agonic line trending southeast across western Michigan to South Carolina, is roughly paralleled by the irregular isogonic lines. In northern Maine, declination, or departure from true north, reaches an extreme of 22 degrees West; in western Washington, more than 24 degrees East. (After the U. S. Coast and Geodetic Survey.)

needle actually points north and south. Therefore, to permit its effective use, the direction and extent of this deflection must be known within relatively narrow limits.

This departure, or the magnetic declination, is the angle between true and magnetic north. It is either east or west, dependent on whether the compass needle points to the east or west of true north. Not only does the direction in which the compass needle points change from place to place, but also from year to year, and even sufficiently during the day in a given place to make it necessary to take the change into account in accurate surveys. For example, if a mile-long line is run at 8 o'clock in the morning, and again about 2 o'clock in the afternoon of the same day, using the same starting point and compass bearing each time, the change in compass direction during that interval of time may be sufficiently great to cause the terminal points of the two lines to be more than 20 feet apart in the two surveys. This is a considerable difference and generally sufficient to be of practical importance.

Because of the great practical importance of knowledge of compass declination, not only for nautical use but for land survey as well, the magnetic work of the Coast and Geodetic Survey has been extended to cover the interior of the United States. This is desirable because nearly all early land surveys in the United States were made by compass, and boundaries in deeds are therefore described by compass bearings. Further, the compass is still much used in travel and survey. Therefore it is essential that the correct allowance be made for declination, especially where deviations reach such extremes as those of 98 to 102 degrees observed by Admiral A. H. Markham in polar exploration. Even in lower latitudes, the declination is often considerable, as shown in Fig. 430, and therefore necessary to take into account in travel for any considerable distance or for surveys of even relatively short lines.

QUESTIONS AND EXERCISES

1. What are the geographical poles? The magnetic poles? Where located?
2. Why is it generally necessary to apply a correction to the compass reading to determine true north? Where would such a correction be unnecessary?
3. What is an agonic line? An isogonic line? Is the agonic line for the United States to the east or west of where you live?
4. What is the departure of the compass needle from true north where you live?
5. Is the departure of the compass needle from true north constant from time to time at a given place?
6. When Columbus crossed the Atlantic, his sailors were disturbed by the changing direction in which the compass needle pointed as they traveled westward. How great a change did they note?
7. Note the irregularities in the northern boundary of Tennessee. What parallel does this boundary follow approximately? Explain how lack of knowledge of compass declination may have caused these irregularities, at least in part.
8. What are some practical uses of knowledge of compass declination? What United States government agency maps compass declination?

Chapter Forty-Six

REPRESENTATION OF ELEVATION AND RELIEF ON MAPS

Representation of Elevation. Elevation, or distance above mean sea level, may be shown on a map by two methods: (1) use of color and (2) by contour lines. When color is used, the various shades of green represent land of slight elevation and below sea level; the yellows, browns, and reds, areas of progressively greater elevation. The exact values assigned to each color may be determined by use of the key which accompanies the map. The use of contour lines to show elevation is discussed later in this chapter under the heading "topographic maps." Examples of such use in your text are afforded by Figs. 181, 184, 189, 195, 196, 197, 202, and many others.

Representation of Relief. Relief, or the degree of surface irregularity of the land, may be shown on a map by either one or by a combination of two of the three following methods: (1) by use of shading, (2) by hachures, and (3) by contour lines. When shading is employed, the colors ordinarily used are either brown or black, the former used by the United States Geological Survey, the latter on maps sold for general use. The second method of showing relief, by use of hachures or lines drawn parallel to the slope, is used for several maps in your text, such as Figs. 156, 273, 280, and 286. The use of contour lines to show relief is discussed later in the chapter under the heading "topographic maps." Illustrations of such use are afforded by Figs. 181, 184, 189, 191, 196, and 206 in the text. Though not designed to show relief *directly*, it may often be inferred from the *pattern* of colors on a map, where color is used to show elevation.

Topographic Maps. A topographic map is one which shows the elevation and other characteristics of the land forms, that is, whether slopes are gentle or steep and the exact degree of slope of surface irregularities of the land. The best method of accomplishing this objective is by use of contour lines.

On the map, Fig. 431, the elevation alongshore at mean sea level, the datum plane from which elevation is reckoned, is 0. Away from the coast, the land surface rises gradually to an elevation of 20 feet, along the line on which this elevation is indicated, which is, therefore, a contour line, or one drawn through points of equal elevation. Still farther inland, the land surface rises to greater elevations, as shown by the numbers on the other contour lines. Where slopes are steep, the contour lines are close together; where gentler, they are more widely spaced. Thus not only do the contour lines show elevation but their spacing indicates steepness of slope.

The contour interval is the vertical interval or the distance ascended or descended in travel from one contour line to the next. Where slopes are gentle, it is desirable to use a small contour interval such as 5 feet in order to show relief effectively, but in very rough or mountainous country it may be necessary to use a larger interval such as 100 feet. Otherwise the contour lines would be so close together as to create confusion and defeat the purpose of using them. It is true, of course, that a large interval does not permit indication of minor surface irregularities, but this omission may be necessary, either where relief is great or where the small scale of the map does not permit more than showing the general details of surface configuration.

Such topographic maps, first used in the early part of the eighteenth century, are often of great value, for they may be so drawn as to show both elevation and relief in great detail. Elevations may be read directly from the contour lines and

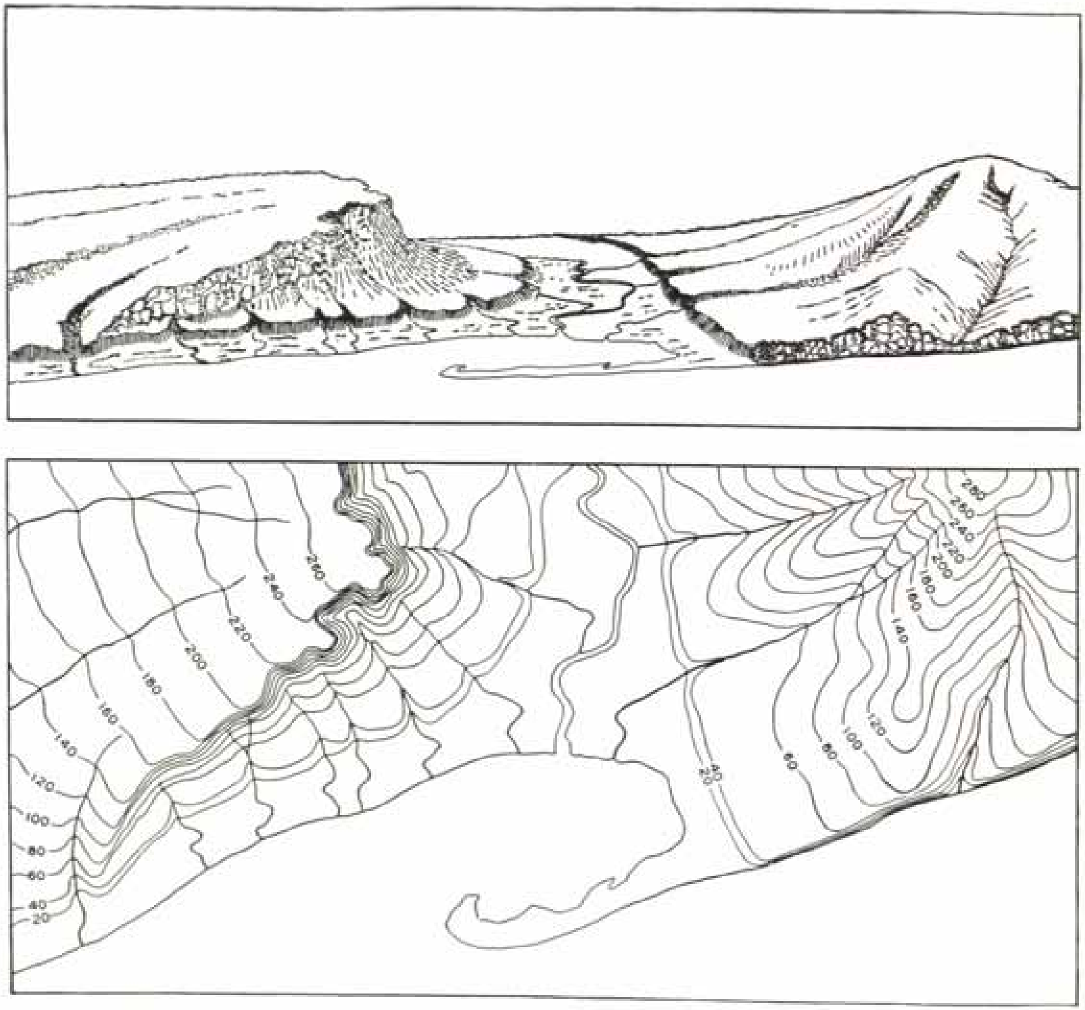


FIG. 431. Sketch of a land area above; a contour or topographic map of the same area below. (After the U. S. Geological Survey.)

estimated accurately for points intermediate between them; relief is indicated by the closeness of the pattern of these same lines. When carrying details of military importance, such maps are known as "military maps."

At the present time, almost all countries publish topographic maps, with elevation and relief shown by contour lines, though the mapping agency differs from country to country. In the United States, these maps, each covering a small area, are made by a division of the Geological Survey. When all are completed, we shall have, for the first time, an accurate, large-scale map of the entire United States.

In printing these maps, three colors are always used, often four, and sometimes five. Blue is used for all water; brown for all elevation, both contour lines and numbers which show exact elevations; and black for the works of man such as buildings and roads. Some maps also show forest in green, and a few of those on a large scale show certain features such as main highways in red. These maps, which should be of great interest to all and of great value to many, are sold at cost by the Geological Survey and, at a small profit, by many stores which stock the sheets of local interest, for which the demand is sufficient to make it worth while.

QUESTIONS AND EXERCISES

1. What is meant by "elevation"? How may elevation be shown on a map? When colors are used for that purpose, what does each represent? What color is used for areas below sea level?
2. What is meant by "relief"? State three ways in which relief may be shown on a map. What are "hachures"? How may relief be inferred in a case where colors are employed on a map to show elevation?
3. What is a topographic map? How is steepness of slope indicated on such a map? How would a vertical cliff be shown on such a map?
4. How may elevation be determined from a topographic map? What is the elevation of Florence, Fig. 184? The elevation of Broad Street School on the same map?
5. What is meant by the "contour interval"? Under what conditions is it desirable to use a small contour interval on a map? A large contour interval?
6. What contour interval is used in Fig. 189? Why is it desirable to use a relatively small interval on this map? What is the contour interval used in Fig. 206? Why is it desirable to use this interval?
7. What is a "military map"? How does it differ from an ordinary topographic map?
8. What agency issues topographic maps in the United States?
9. What colors are used on the topographic maps published in the United States? What does each color show?
10. Of what practical value are topographic maps?

SELECTED REFERENCES

Beaman, W. M., *Topographic Instructions of the United States Geological Survey*, Bulletin 788-E, Washington, 1928.

This manual, issued primarily for those engaged in making topographic maps, will be found of interest, for it affords a discussion of methods employed in making such maps.

Deetz, C. H., *Cartography*, Special Publication No. 205, 2d ed., U. S. Coast and Geodetic Survey, Washington, 1943, Figs. 16, 17, 18, 19.

Fig. 16 shows a topographic map in color; Figs. 17 and 18, relief shown by hachures; Fig. 19, a combination of hachures and contour lines to show elevation and relief.

Chapter Forty-Seven

LAND SURVEY

Land Survey. In the absence of fixed reference points established by previous surveys of considerable areas, it becomes necessary to describe the boundaries of small tracts of land by reference to streams, established highways, trees, and markers such as stones. When this is done, lengths of boundaries are determined by measure, and the direction of their trend is stated by compass direction. This is known as location by "metes and bounds."

This system of location is used extensively in many parts of the world and was followed during

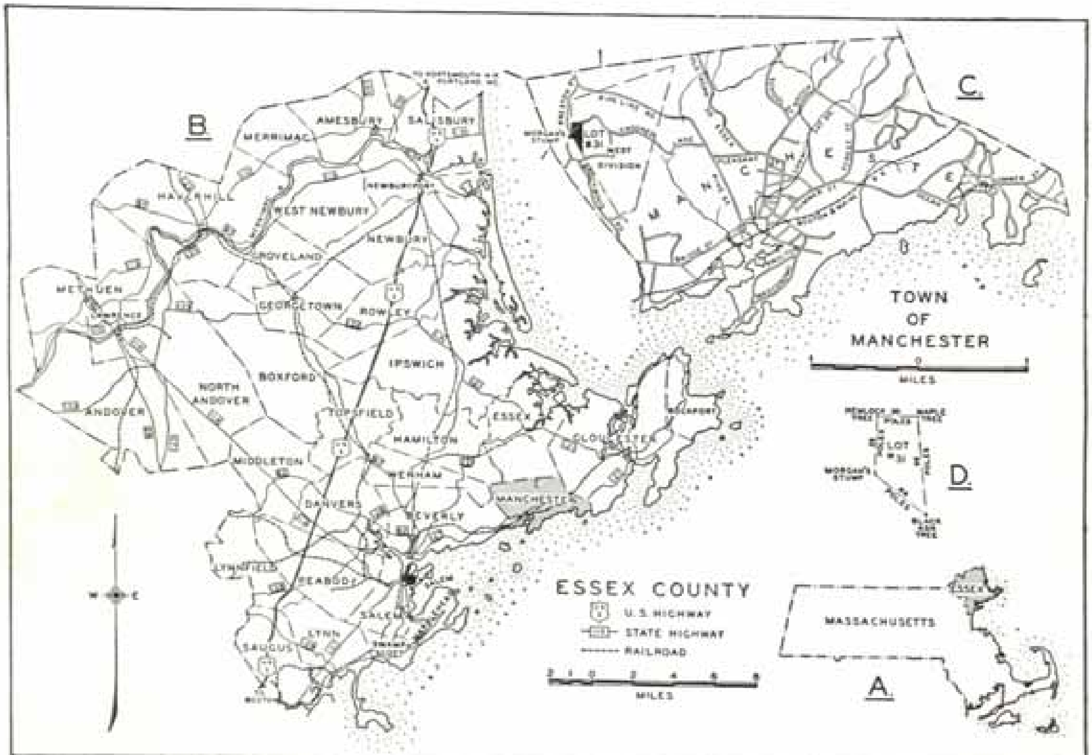


FIG. 432. Maps to show the irregular boundaries of counties, townships, and individual landholdings in the area of early settlement in eastern Massachusetts. "A" shows the location of Essex County with reference to the state; "B" that of the Town of Manchester in the county. In "C," the solid black area, enlarged in "D," is an individual landholding, allocated to Captain Thomas West in 1699, when the common holdings of the Town of Manchester, divided into north, east and west divisions by measure, and markers of stakes and blazed trees, were subdivided among individual owners. (Based on maps and data by R. C. Allen, and R. E. Evans, County Engineer.)

the Colonial period and for some time thereafter in the United States in the absence of previous accurate surveys. Therefore it is still in common use in the states of earlier settlement. (See Fig. 432.) Though this is a simple method for describing a small tract of land, rivers change their courses, the compass needle varies in its pointing from time to time, and landmarks such as trees die and decay. Therefore such a system often gives rise to uncertainty as to the exact location of boundaries and may cause much litigation. Further, such a system of survey is accompanied by great variation in description and very irregularly shaped landholdings, as indicated in Fig. 432. There, the legal description of the tract "D" is as follows: "The thirty-first lot in the Westerly Division of Common Rights in the Town of Manchester, made in the year of our Lord one thousand six hundred ninety-nine." This tract is bounded as follows: 'At the northeast corner with a maple tree between him (Captain West) and Abraham Masters, from that westerly 30 poles to a hemlock tree between him (Captain West) and Abraham Masters, from that southerly westerly 39 poles to Morgan's Stump, from that southeasterly 44 poles on said West's farm line to a black oak, and from that 66 poles northwestward to the first point." This tract of land of approximately 10 acres is today subdivided into several smaller parcels, with the subdivision based on the original description.

The system of description by metes and bounds has so many obvious disadvantages that, when the land north and west of the Ohio River passed into national ownership, Congress provided for its survey into quadrangular units, each 6 miles "square" and containing approximately 36 square miles, Thomas Hutchins being appointed "Geographer of the United States" to carry out this plan, supposed to have been sug-

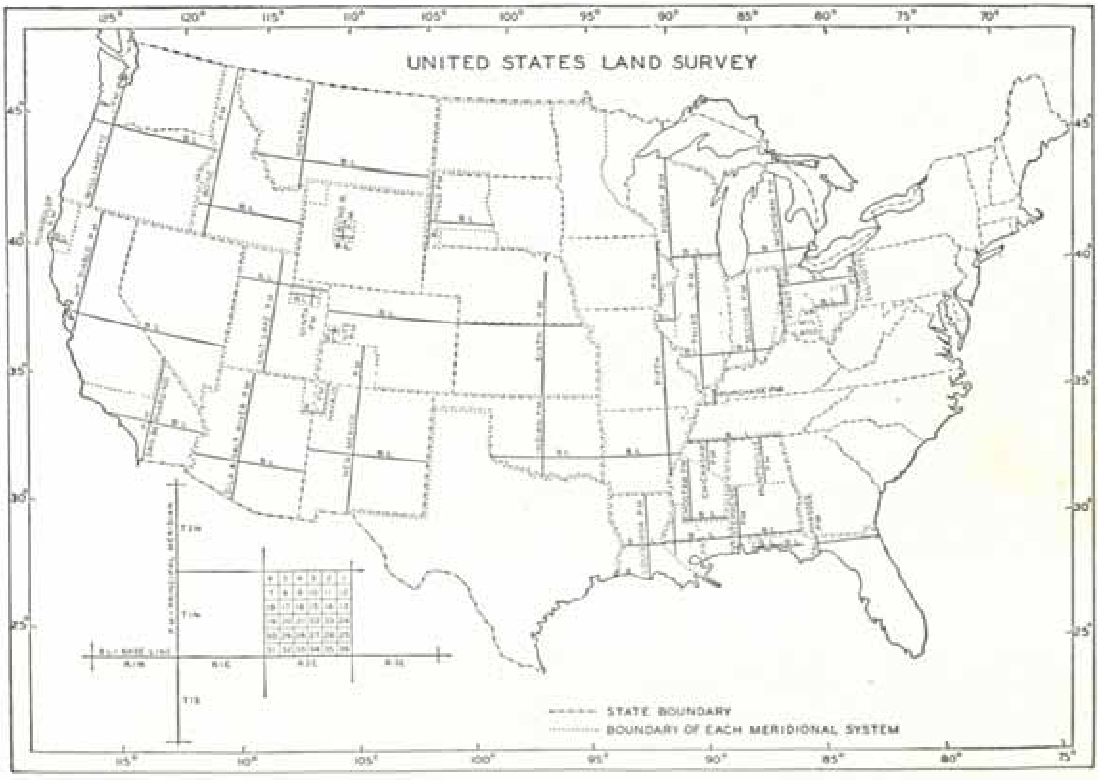


FIG. 433. United States land survey by township, range, and section, showing the meridians from which townships are numbered east and west, and the base lines from which they are numbered north and south. In the lower left hand corner, T.1 N., the first town north of the base line, R.2 E., the second east of the meridian or range line, is subdivided into 36 sections, each numbered correctly. (After U. S. Land Office Map.)

gested by Thomas Jefferson. The plan as embodied in law provided that "The surveyor . . . shall proceed to divide the said territory into townships of six miles square, by lines running due north and south, and others crossing these at right angles, as near as may be." Thus townships are bounded by parallels and meridians, the convergence of the latter making each contain only approximately 36 square miles. The system as it is in effect today is described in the following paragraph and illustrated in Fig. 433.

Townships are numbered east and west from principal meridians, shown in Fig. 433. Thus, Town 5E, will be the fifth township east of the principal meridian from which it numbers. The townships are similarly numbered north and south from selected parallels or base lines, shown in Fig. 433. Each township, which is 6 miles "square" and contains approximately 36 square miles, is subdivided into 36 sections, each containing 1 square mile or 640 acres. Thus a farm of 160 acres, occupying the northeast quarter of Section 6 in the diagram in the lower left-hand corner of Fig. 433, is described as follows: N.E. ¼ of Sec. 6, T1 N., R.2E. This means that it is the northeast quarter of the northwest section of the first town north of the base line and the second east of the principal meridian.

This system of survey by township, range, and section has numerous obvious advantages, including that of fixing boundaries definitely and possible of reestablishment if fences or other landmarks are destroyed. It likewise makes for a rectangular system of highways at regular intervals by contrast with those where farms are described by metes and bounds.

QUESTIONS AND EXERCISES

1. What is land description by "metes and bounds"? Under what conditions is such a description necessary? Why was it used in New England during the Colonial period? Is it used there today?
2. In what terms and in what manner is a tract of land described by metes and bounds? What are some of the disadvantages of such a system of land description?
3. When was the township, range, and section system of land survey initiated? Who is credited with suggesting this system of land survey? Who carried out the first surveys of this type in the United States?
4. What parts of the United States have a township, range, and section system of land survey? What is meant by the "base line"? The "range line"?
5. How many sections in a township? How are they numbered? How many acres in each section?
6. If you owned the N. ½ of the N.W. ¼ of Sec. 36 in a township, how many acres of land would you own?
7. How many miles will it be from the south boundary of T.10N. to the base line from which the township is numbered?
8. What system of land survey is used in your home state? What are some of the advantages of a township, range, and section system of land survey? How does it affect the road pattern? Is this an advantage or a disadvantage? In what respects?

SELECTED REFERENCES

Johnson, W. E., *Mathematical Geography*, American Book Company, New York, 1907, Chap. XI.

This reference affords a considerable and interesting amplification of the discussion of land survey in the text. It should prove of practical value.

Chapter Forty-Eight

SOLAR RELATIONS

The Earth and the Solar System. The earth is part of the solar system, which comprises nine planets with their satellites or moons; several hundred smaller planets known as "asteroids" or "planetoids"; and occasional visitors such as comets and meteors. The planets with their satellites and the asteroids all revolve in an approximately common plane around a central incandescent body, the sun, from which the earth derives sufficient but not too much heat to make life possible on its surface. All the planets, including the earth, are relatively small by comparison with the sun, which has a diameter of 866,500 miles, more than 100 times that of the earth and in excess of 9½ times that of Jupiter, the largest of the planets. It is so huge, indeed, that a man who weighed 150 pounds on the earth would there weigh over 2 tons, because of the greater pull of gravity. Thus he would be unable to lift his arm and it is doubtful whether his bony framework would support his body.

Though seafarers observed the "bended sea" as long ago as the time of Homer, early accounts of the earth accorded it a flat surface and tales of mariners and others which indicated its sphericity were classed as fantastic fabrications. The first record of a dawning realization that the earth is speroidal in form is dated about 500 B.C., but within a relatively short time thereafter, approximately 300 B.C., Aristarchus proposed the heliocentric theory, which taught that the earth rotates on its axis and revolves around the sun. This was soon accepted by most scholars of that day, though later discarded and not revived until the time of Copernicus (1473–1543), who again promulgated the teachings of Aristarchus, so long in disrepute. However, defenders of this theory were forced to resort to humiliating subterfuges to support it, for at that time such beliefs were thought by many to be heretical in character, because contrary to the teachings of the Scriptures.

Rotation of the Earth. To most early observers, the earth, disregarding minor surface irregularities, appeared to be flat and covered by the rotating dome of the sky, in which the stars occupied fixed positions. This was because conditions on the earth are, from the standpoint of the individual observer, much the same as though he lived at the center of the rotating floor of a circular room with a dome-shaped ceiling. Under such conditions, the ceiling would appear to turn, though it would actually be the floor which was in motion. Similarly, it is the earth which rotates, not the dome of the sky which covers it. This movement causes day and night, for when a place is on the side of the earth facing the sun and therefore receiving light, it is daytime; when on the side turned away from the sun, it is night.

Revolution of the Earth. That the earth revolves around the sun has been believed for more than 2000 years, though positive demonstration of that fact has been much more recent. Today, however, we know definitely that the earth travels around the sun in an elliptical path or orbit. Though the ellipticity is relatively slight, it is sufficient to cause the distance between the earth and the sun to vary from approximately 91,500,000 miles the last of December to as much as 94,500,000 miles about the first of July. Thus the average distance is roughly 93,000,000 miles. In its movement about the sun, the earth travels a total of 584,000,000 miles each year, rotating daily on its axis, which is inclined to the plane of the orbit in which it revolves, or the plane of the ecliptic, at an angle of slightly more than 66½ degrees. Thus the axis makes an angle of

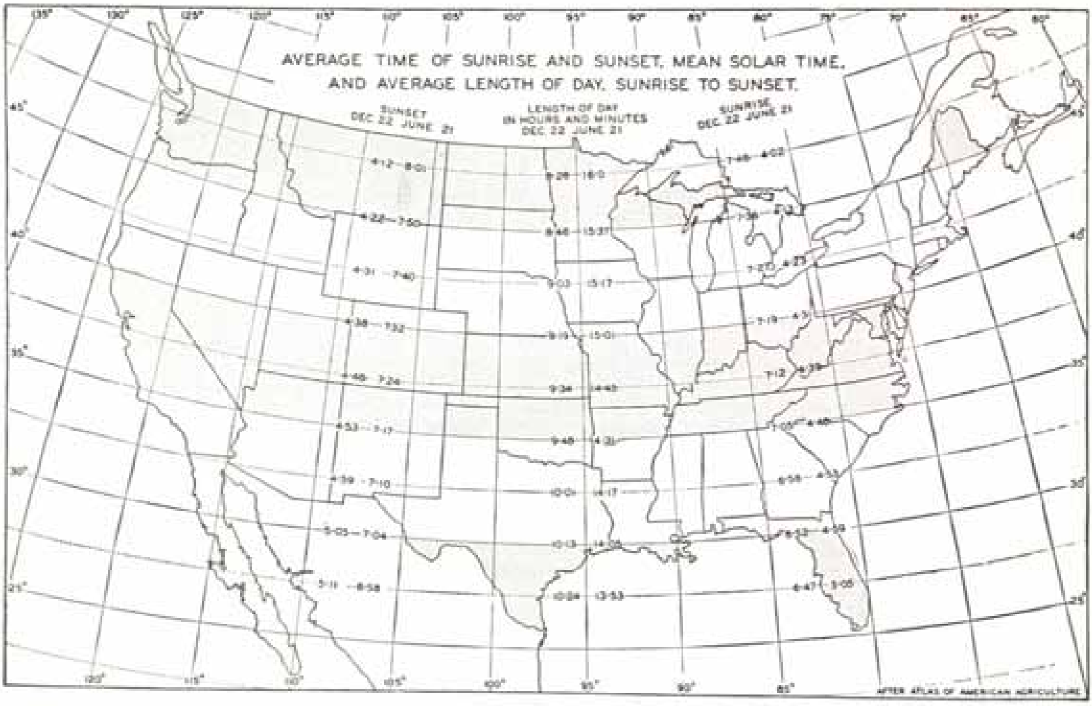


FIG. 434. Average length of the daylight period in the latitudes of the United States. Study of the map will reveal that the sun rises earlier and sets later in summer; and rises later and sets earlier in winter in the north than in the south, so that summer days are much longer and winter days much shorter along the Canadian Boundary than in areas bordering the Gulf of Mexico. This is one of the reasons why seasons are more marked in the north than farther to the south. (After the Atlas of American Agriculture.)

nearly 23½ degrees with a vertical to the plane of the ecliptic.

If the earth revolved around the sun on a vertical axis, the sun's rays would always strike at the same angle at any given place and would always be vertical at the equator. Similarly, days and nights would be equal in length everywhere on the earth's surface, now true only at the equator. However, since the earth's axis is inclined rather than vertical, the latitude in which the sun's rays strike vertically varies from day to day throughout the year and the length of the daylight period alters as well. (See Fig. 434.)

On June 21, for example, the sun's rays are vertical at the Tropic of Cancer, 23½ degrees north of the equator. This is the time of the summer solstice, so called because the "sun then apparently stands still in its northward motion." Six months later, on December 22, they are vertical at the Tropic of Capricorn, 23½ degrees south of the equator. This is the time of the winter solstice, when once again the sun appears to stand still, but this time in its southward motion. Midway between these two dates, on March 21 and September 22, the sun's rays are vertical at the equator, half-way between the Tropics of Cancer and Capricorn. These are the dates of the two equinoxes, for then day and night are equal in length everywhere on the earth, as well as at the equator. Thus the sun's vertical rays migrate north in our summer and south in our winter over a belt 47 degrees of latitude in width; half north, half south of the equator. This belt, often referred to as "the tropics," is that part of the earth's surface where the sun's rays are vertical at each parallel twice each year, once when they migrate north; again, when they return south.

At the time of the sun's northward migration, the daylight period is longer in the Northern Hemisphere, increasing in length with distance from the equator. In very high latitudes, indeed, in the Land of the Midnight Sun, it is daylight, not only throughout a 24-hour period, but in

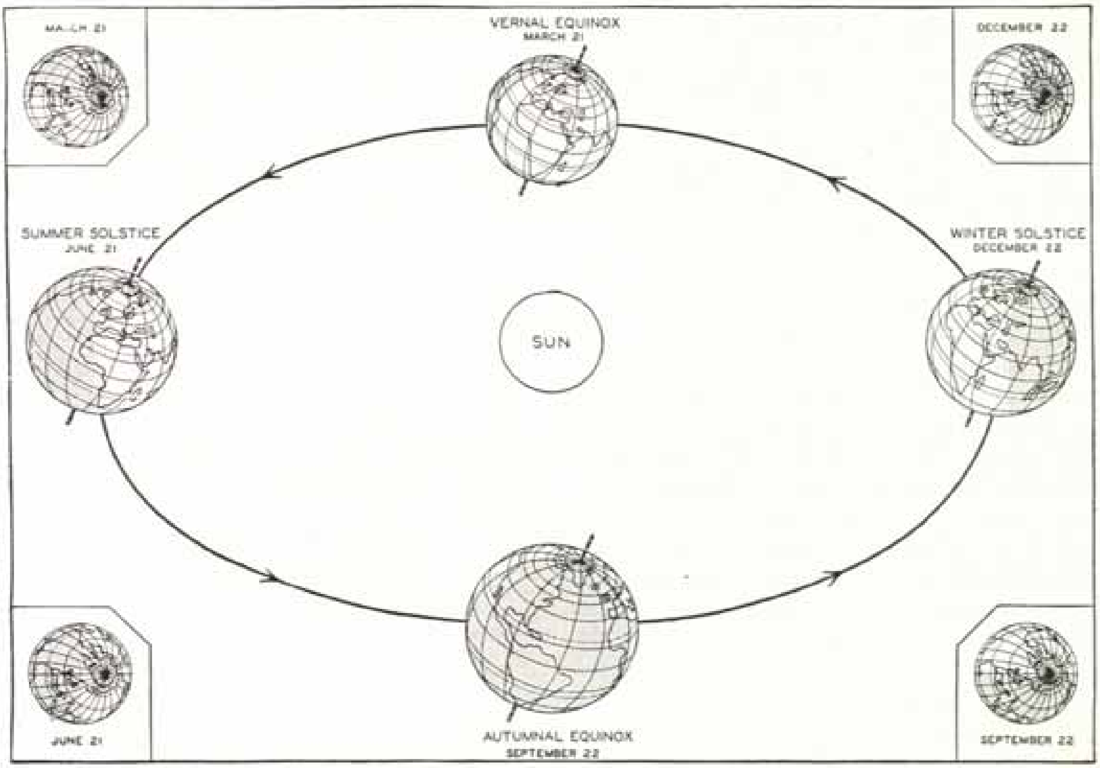


FIG. 435. Positions of the earth and sun at the times of the equinoxes and solstices.

At the times of the two equinoxes, March 21 and September 22, the sun's rays are vertical at the equator and days and nights are equal in length everywhere on the earth's surface, for the circle of illumination, or the circle which marks the boundary between daylight and darkness, passes through the poles, dividing all parallels into two equal parts.

At the time of the summer solstice, June 21, the sun's rays are vertical 23½ degrees north of the equator, at the Tropic of Cancer. At this time, the daylight period in the Northern Hemisphere is longer than that of darkness, increasing from 12 hours in length at the equator to 24 hours at and within the Arctic Circle. Therefore it is summer in the Northern Hemisphere; winter in the Southern.

At the time of the winter solstice, December 22, the sun's rays are vertical 23½ degrees south of the equator, at the Tropic of Capricorn. Therefore days are short and nights are long north of the equator, ranging from a maximum of 12 hours at the equator to 0 at the Arctic Circle. Thus it is winter north of the equator, summer to its south.

many places for three months or more at a time. When the sun's rays are vertical near the equator, the periods of darkness and daylight are approximately equal in length in most latitudes, but when they are vertical south of the equator, days become long south of the equator and short to its north. Within the Arctic Circle, night is then continuous, lasting for many days in areas near the North Pole.

The Seasons. The seasons as we know them in intermediate latitudes are marked by differences in temperature and often by incidental variation in amount and form of the precipitation as well. In the tropics, by contrast, where change in temperature from month to month is never great, and often so small as to be virtually unnoticeable, either at sea level or at elevation, the year is divided into seasons on the basis of precipitation differences; rainy and dry rather than hot and cold seasons being recognized. In this chapter, the discussion will be limited largely to explanation and consideration of those seasons which are accompanied by considerable to great temperature change. These are summer, fall, winter, and spring.

It is a matter of common observation and ex-

perience that the latter part of December, all of January and February, and much of March tend to be cool to cold in all parts of the United States. Similarly, it is generally true that June, July, and August are commonly warm to hot. Intermediate between these warmer and colder parts of the year, the spring and fall months are characterized by more moderate temperatures. These variations must, of course, result from the fact that the various areas of the United States receive more heat from the sun at some seasons than at others.

It is apparent that part of this difference must arise from the fact that daylight periods are longer in summer than during the winter, for heat is received from the sun during the daylight period only. Therefore the longer this period, the more heat received, other conditions remaining constant. In winter, by contrast, when days are short and nights are long, much less heat is received and temperatures are correspondingly lower. The farther one travels from the equator, the greater the difference in the length of the daylight period between summer and winter, therefore the greater the temperature difference between these two seasons resulting from this cause. (See Fig. 434 and Table IX, Appendix.) This variation in length of the daylight period results from revolution of the earth around the sun on an axis which maintains a fixed, inclined position with reference to the plane of the ecliptic, so that all its positions are parallel to one another. This is what is meant by "Parallelism" of the axis.

Another difference in the behavior of the sun during summer and winter is likewise observed by most people who live in intermediate latitudes. This is that the sun is more directly overhead and its rays are more nearly vertical in summer than they are during the colder months. As a result, they have more heating power in July than in January and hence add to the effectiveness of the long period of daylight in causing higher temperatures. This lesser obliquity of the sun's rays during the summer months of the Northern Hemisphere results from the shifting of the sun's vertical rays with the changing seasons, which has been considered earlier as a necessary accompaniment of the revolution of the earth around the sun with its axis inclined to the plane in which its orbit lies.

Thus the higher temperatures of summer result from a longer period of daylight combined with the fact that the more nearly vertical rays of that season possess greater heating power. In the tropics, by contrast, where days are essentially uniform in length throughout the year, and the verticality of the sun's rays varies but slightly, the amount of heat received is much the same during the different months of the year and seasons based on temperature differences cannot be recognized. This variable effectiveness of the sun in warming areas in intermediate latitudes, then, results from the rotation of the earth on its axis once each 24 hours and its revolution around the sun once each year, on an axis which points constantly in one direction, but is inclined with reference to the plane in which the earth revolves around the sun.

QUESTIONS AND EXERCISES

1. What bodies make up the solar system? Name the planets. What location does the earth occupy with reference to the sun and the other planets?
2. What is meant by the "heliocentric theory"? Why was it difficult for Copernicus to advocate this theory openly?
3. Why do the heavens appear to rotate around the observer? What causes the apparent rotation of the dome of the sky?
4. For how long a period of time has it been believed that the earth revolves around the sun? What is the shape of the earth's orbit? How does this affect the distance of the earth from the sun at different times of the year? What is the length of the earth's orbit in miles?
5. If the earth revolved around the sun on an axis which was vertical to the plane of the ecliptic, how would this affect the length of the daylight period and our present seasons in intermediate latitudes? What is the actual inclination of the earth's axis?
6. Where are the sun's rays vertical on June 21? On December 22? What special names are applied to these two dates? What are the equinoxes and when do they occur? Why are they so called?
7. What is the length of the daylight period north of the Arctic Circle at the time of the summer solstice? At the time of the winter solstice? What is the length of the daylight period at the equator on all dates? How does this affect annual temperature range at the equator? The seasons?
8. In approximately what latitude will the sun's rays be vertical May 21? On approximately what

dates will the sun's rays be vertical 8 degrees south of the equator?

9. On what basis is the year divided into seasons in the tropics? Why?

10. What causes the seasons as we know them in intermediate latitudes? Why are they reversed in the Northern and Southern hemispheres? Is there any advantage to this and, if so, what?

SELECTED REFERENCES

Johnson, W. E., *Mathematical Geography*, American Book Company, New York, 1907, Chap. VIII.

This chapter contains a more extended discussion of the seasons than that in your text, but it is not highly technical and should be interesting.

Chapter Forty-Nine

MEASUREMENT OF TIME

The Reckoning of Time. Though the present importance of reckoning time and fixing exact dates is a relatively recent development, and though the writings of Herodotus, sometimes known as the "father of history," would delight many a modern "student," for they have no dates to be learned, man has been interested in recording the passage of time since the dawn of history, when he carved his calendars of stone. Even before 3000 B.C. the Babylonians are supposed to have reckoned time in years having 12 months each; the Egyptian system of some 2500 years later was the basis for the so-called "Julian calendar," widely used in the Western world until the sixteenth century. In the Americas as well, attempts were made to fix the sequence of events on a time scale, the Aztecs being credited with having a calendar with a year of 365 days in length. These early calendars, however, had certain defects. Therefore they have been modified for present-day use, in order to reconcile the calendar year with the "tropical year" as regards length.

The Year. The tropical year, or the year whose length is determined by the number of days required for the sun's vertical rays to travel from one tropic, the Tropic of Cancer, to the other, the Tropic of Capricorn, and back again to the Tropic of Cancer, is the year to which we ordinarily refer, and to which we endeavor to adjust our calendar. However, the mean length of this year is not 365, but 365.2422 days, or 365 days, 5 hours, 48 minutes, and 45.51 seconds. Thus it is necessary to introduce leap year, so that the year of our calendar will not differ too greatly from the tropical year over a relatively short period of time.

The Calendar. In ancient times, the moon rather than the sun was the common measurer of time, and even now the dates of some religious observances such as Easter are fixed with reference to the moon. However, when the attempt is made to divide the year into months on the basis of the solar day of 24 hours, the lunar month of about 29½ days, and the tropical year of 365.422 days, the subdivisions do not add up exactly to the total, the year. This introduces confusion, which has led to the development of different calendars, several of which are still in use in various parts of the world, though the one most widely employed is the Gregorian, devised in 1582 and soon thereafter coming into widespread use. When this was adopted in Great Britain, displacing the Julian calendar used previously, it made a change of date necessary. Thus, awakening on what would have been September 3, 1752 by the Julian calendar, Englishmen found it was September 14 and rioted through the London streets, shouting "give us back our 11 days."

In the Gregorian system, by providing for a leap year in all years divisible by 4, except those centurial years not divisible by 400, the error of the calendar is so small that, over a period of 4000 years, the calendar and the tropical year differ less than a single day. In the year as fixed by this calendar, the months are of unequal length so that it is common to learn the number of days in each as follows:

> Thirty days hath September, April, June, and November.
> All the rest have thirty-one, save the second one alone,
> Which has four and twenty-four, till leap year gives it one day more.

This unequal number of days in the months has certain disadvantages such as those arising when hiring help or renting property by the month.

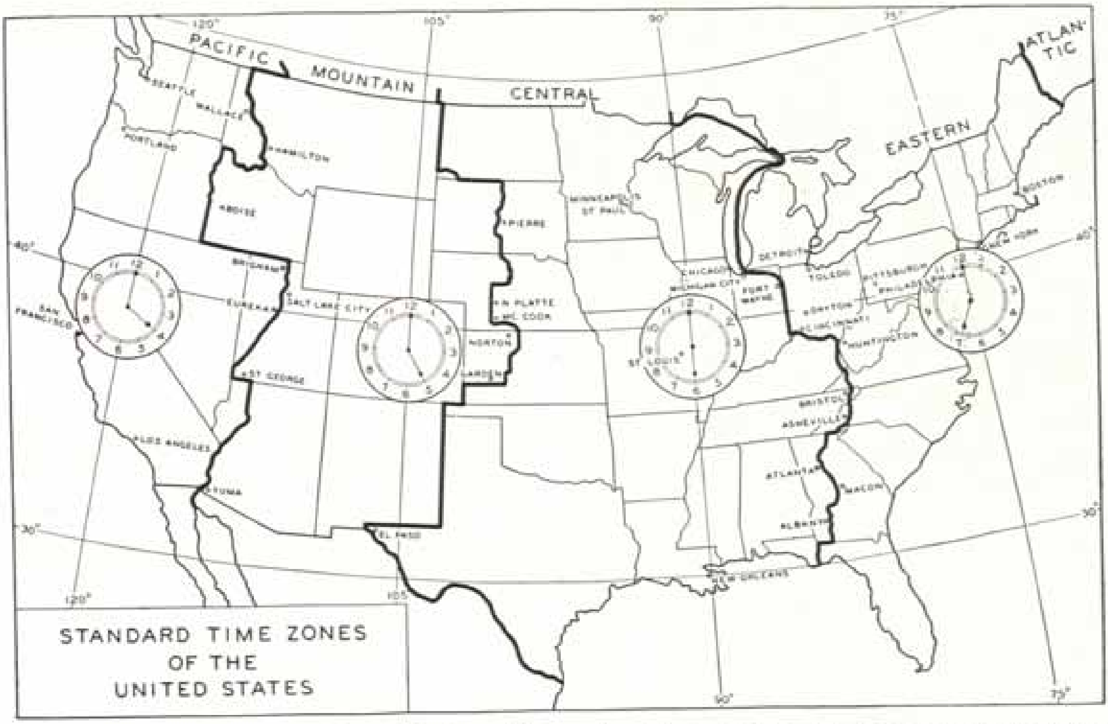


FIG. 436. Standard time belts of the United States, in each of which the time kept is the local time of the mid-meridian. The clocks on these meridians show that it becomes progressively earlier in the day toward the west, at the rate of 1 hour for each belt of 15 degrees of longitude in width. Therefore Pacific time is 3 hours earlier than Eastern time. When daylight saving time is in local use, the Central Belt keeps Eastern time; the Eastern Belt, Atlantic time; and others make similar changes.

This has of late years led to some agitation for changing the month-division of the year. Indicating the interest in calendar change is the fact that a committee set up by the League of Nations has worked on 185 new versions. The best known of these proposed changes is the 13-month calendar, in which the first of each month would fall on Sunday, but no country has adopted it as yet.

Longitude and Time. Within the year and during the day, the sun is our timekeeper, for the mean solar day, or the average interval from sun noon to sun noon, the time of day when the sun's rays are most nearly vertical, is the day as commonly reckoned, a period of 24 hours in length. Each day of this length, the earth completes one rotation, thereby producing an apparent journey of the sun around the earth. As it turns, the sun's rays, which remain constant in location, strike different portions of the surface of the rotating earth, during the entire 24-hour period covering 360 degrees, or the complete circumference, at the rate of 15 degrees each hour.

Since the earth rotates from west to east, the sun's rays reach points to the east earlier, and those to the west later, when the earth has turned sufficiently to bring them into the path of the sun's rays. Thus the sun rises earlier to the east of us and later to our west, which means that it is later in the day to the east and earlier to the west. Therefore, when it is noon at Chicago, it is afternoon at New York, and forenoon at San Francisco.

The change in time between places east and west of one another is gradual, amounting to 1 hour for each 15 degrees of longitude, since this is the length of time required for the sun's rays to cover that east-west distance. Therefore if a man sets his watch to the correct local time and then travels west, where it is earlier in the day, his watch will be fast; if he travels east, it will be slow. Further, to enable keeping correct time, as measured by the sun, it would be necessary that he reset his watch steadily as he traveled either east or west. To eliminate this difficulty, it

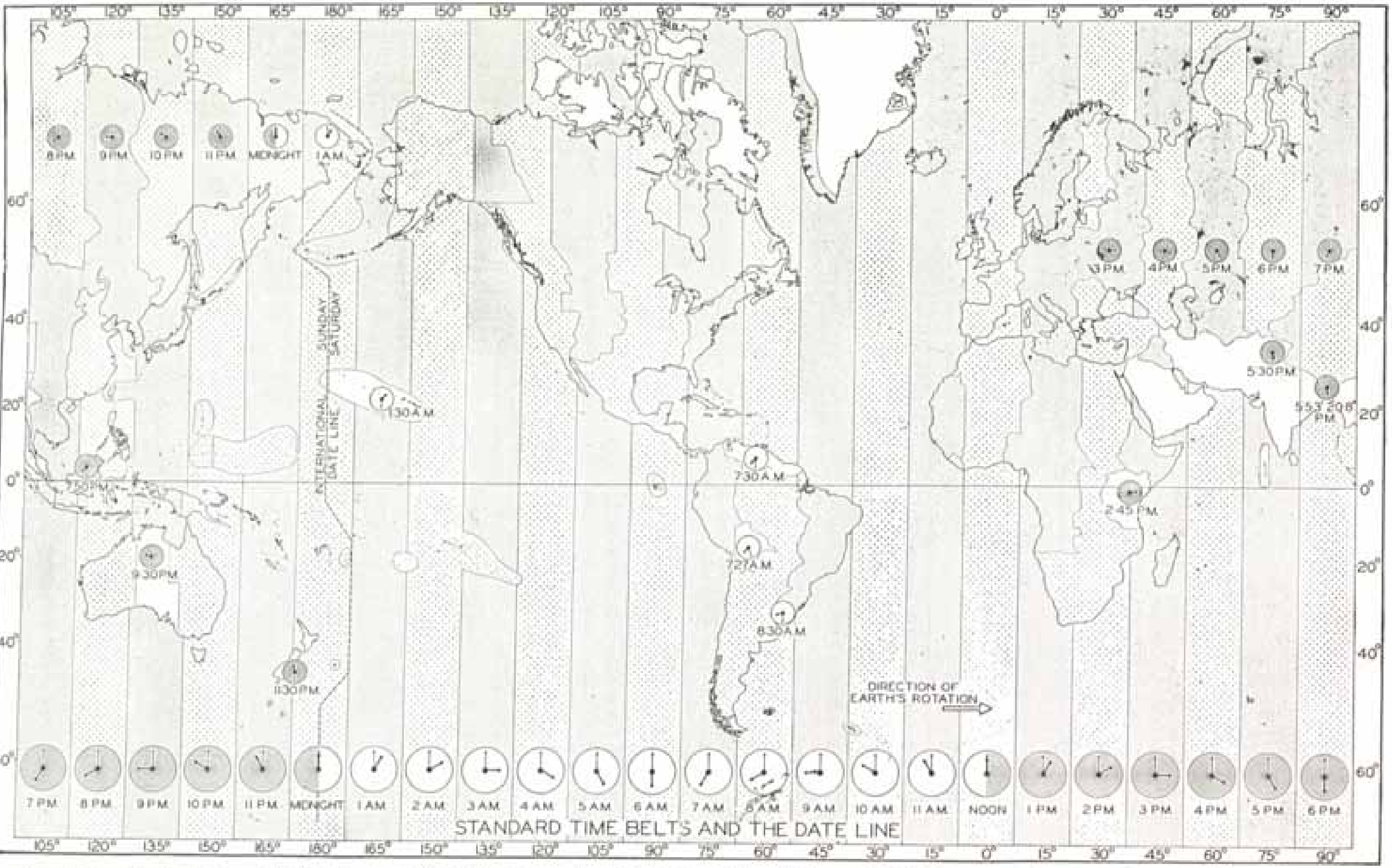


FIG. 437. Standard time belts for the world and the International Date Line. Time belts are all 15 degrees wide and regular in width over the water, for this causes no complications; over the land they vary in width to suit local convenience. In Mexico, for example, time is uniform everywhere, except in Lower California, though not over the adjacent oceans. Locally, also, the time kept may not conform to the standard system. The International Date Line indicates the line along which the date changes. Crossing it from east to west, Saturday becomes Sunday and one loses a day; crossing it in the reverse direction, Sunday becomes Saturday, and a day is gained.

is conventional practice today to keep what is known as "standard time."

Prior to adoption of this practice, people kept the local time of the nearest city which, until the advent of railroads and more extensive travel, caused little inconvenience. With increasing rail construction and use, great confusion resulted, for not only did the railroad time differ from that of each locality, but even that used by the railroads often varied, each rail line often having an arbitrarily chosen time of its own. Thus there might be several correct times in any given city: one the local time, and one for each of the rail lines which served the community. In those days, when one contemplated a trip by rail, he found it necessary to make a computation to determine when his train would leave, for the local time and that of the railroad were not the same. In fact, the times were often "very much out of joint" in those days. In 1883, however, the railroad associations agreed on a uniform system, which is now the legal time and in use by practically all persons in the United States, except as complicated by daylight-saving time, which is nothing more than keeping the standard time of the belt immediately to the east.

This system involves division of the United States into time belts, as shown in Fig. 436, each keeping the time of the mid-meridian of its belt. Thus the Eastern belt uses the mean time of the 75th meridian; the others, the times of the meridians shown in Fig. 436. With this procedure, it is now necessary to change time only in travel from one belt to the next, and the change is always exactly 1 hour. The irregularities of the boundaries of the belts result from an endeavor to accommodate the system to the convenience of large cities.

The Date Line. When one travels west, the day is lengthened because the run rises and daylight comes later; when to the east, the reverse occurs, for the sun rises earlier. This change amounts to 1 hour for each 15 degrees of longitude covered. Therefore, in traveling entirely around the earth, or 24 times 15 degrees, in a westerly direction, an entire day is lost; in an easterly direction, a day is gained. Thus the sailors of Magellan, on returning to Spain in 1522 after having circumnavigated the globe, arrived, according to their reckoning on September 6, though it was actually September 7, for they had lost a day.

To avoid this difficulty, it is necessary to establish a line where the date will change. This line is known as the "international date line." In location, it roughly follows the 180th meridian, as shown in Fig. 437, for this causes a minimum of inconvenience, since it passes through areas where few people live. If the 90th meridian West rather than the 180th were used, when it was Sunday in Chicago and points to its east, it would be Monday in Minneapolis and points to its west. If this were so, a traveler leaving Minneapolis late Sunday night would arrive in Chicago early Sunday morning, which would be confusing at best. Further, there would be two celebrations of the Fourth of July and two election days, one east, the other west of the date line, for cities only a few miles apart. In crossing the line in mid-Pacific, the procedure is simple. Crossing to the west of the line, the calendar is set one day ahead; crossing to its east, back one day. Thus Tuesday becomes Wednesday, or Monday, and one either loses Tuesday or has two, dependent on his direction of travel. In practice, this is less confusing than it may appear.

QUESTIONS AND EXERCISES

1. Why was accurate reckoning of time less important in the past than it is at the present day? How early did man begin to use a calendar? How did the early calendars compare with those of present?
2. What is meant by a tropical year? A calendar year? What relation does one bear to the other?
3. What difficulties are encountered in adjusting the calendar to the tropical year? How has this problem been solved?
4. What is meant by leap year? When do leap years occur? Why is the present unequal number of days in the months a disadvantage? What proposal has been advanced to remedy this?
5. How many degrees of longitude are covered by the sun's rays each 24 hours? How many degrees each hour? In what direction does the earth rotate on its axis? How does this affect the time at New York City by comparison with that at Los Angeles?
6. What is meant by standard time? What is the width of the standard-time belts over the oceans? Why do they vary in width over the land? Do all areas keep standard time? In travel from New

York to San Francisco, what change and how much would it be necessary to make in resetting a watch so that it would register correctly?

7. Why did the sailors of Magellan lose a day in their reckoning of time when they circumnavigated the globe? How is this prevented today?

8. Why is the date line located in the mid-Pacific rather than where it would cross large bodies of land? What would be some disadvantages of having it cross important, densely populated land masses?

SELECTED REFERENCES

Harrison, Lucia C., *Daylight, Twilight, Darkness, and Time*, Silver Burdett Company, New York, 1935.

This reference deals with the distribution of daylight, twilight, darkness, and time on the earth and their relationship to human affairs.

Johnson, W. E., *Mathematical Geography*, American Book Company, New York, 1907, Chaps. IV, V, VII.

These chapters discuss time, the calendar, and the date line. The student will find the last of the three of particular interest.

Chapter Fifty

CLIMATIC TYPES

Climatic Classification. In classifying climates, it is desirable to recognize the minimum number of types which will include effectively the varied combinations of weather conditions, for if the number is too large the objective of classification is not realized. Further, in definition of types, the critical climatic elements which serve as the basis for their identity are best described quantitatively rather than by expressions which have relative values only. Thus a statement of temperatures in degrees is preferable to one in terms such as "hot," "warm," or "cold"; and one of rainfall in inches, rather than as "heavy," "moderate," or "light."

The Köppen system of classification possesses this advantage, therefore it will be followed in this chapter. In its extended form, however, nearly 40 subtypes are recognized, which is somewhat confusing to one who desires only a general picture of the world's climates. To eliminate this difficulty, the number of types discussed in the following pages has been reduced to 15, even though this has necessitated inclusion of some diversity of conditions within the limits of certain types recognized. Further, minor irregularities of boundaries between types have been eliminated, with simplicity rather than strict accuracy as the objective. For more detailed and specific maps, the student is referred to the selected references at the end of the chapter.

Major Subdivisions of the Climatic Classification. In this classification of climatic types, three major subdivisions are recognized. These are the dry, humid, and polar climates. The first two are distinguished on the basis of rainfall; the last on that of temperature. In the "B" or dry types, the precipitation is always scanty and sometimes very light, the exact amount varying with temperature, which affects the rate of evaporation and hence the amount of water required to support plant life. In general, vegetation is sparse and drought resistant in character in areas with such climates. In the humid climates, the "A," "C," and "D" types, the rainfall is sufficient to heavy and vegetation is more luxuriant. In the polar or "E" types, low temperatures restrict both plant and animal life. Each of these major types is subdivided: the "A" into two, the "B" into two, the "C" into four, the "D" into four, and the "E" into two divisions. In addition, an "H" or highland type, reflecting the effects of elevation, is recognized. This makes a total of 15 subtypes, each of which is described in the following pages.

Tropical or "A" Climates. These are distinguished from other humid climates on the basis of temperatures, being characterized by an average of 64.4°F. or over during the coldest month of the year. If the rainfall of an area with such temperatures is ample in amount and well distributed throughout the year, its climate is of the "Af" or Tropical Rain-Forest type. The second term of the letter designation, or "f," is derived from the German word "feucht," meaning "wet"; the name, "Tropical Rain-Forest Climate," from the luxuriant forest growth. If, by contrast, the winter months are dry, the climate is of the "Aw" or "Tropical Savanna" type, the "w" referring to the dry winters, the term "savanna" to the characteristic grassland vegetation.

Tropical Rain-Forest or "Af" Climate. This type of climate, with its continuously high temperatures, 64.4°F. or over, and its abundant, well-distributed rainfall, is confined to a belt about 10 degrees of latitude in width, located on either side of the equator, with tongues extending north and south into trade-wind regions on east-facing coasts backed by highland barriers. Temperatures, not only the actual but the

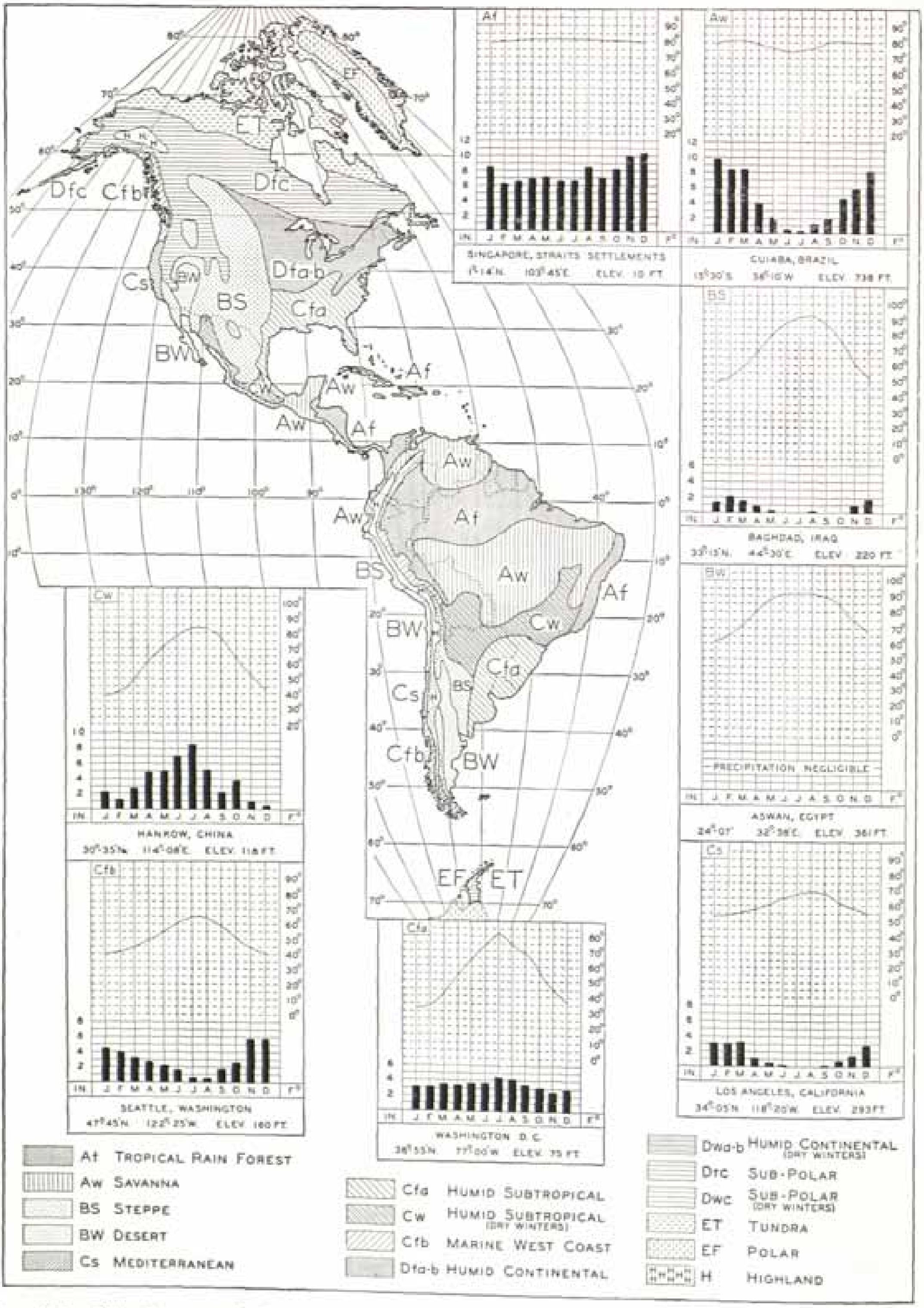


FIG. 438. Climatic types of the Americas and adjacent lands. (Modified from Köppen and Geiger.)

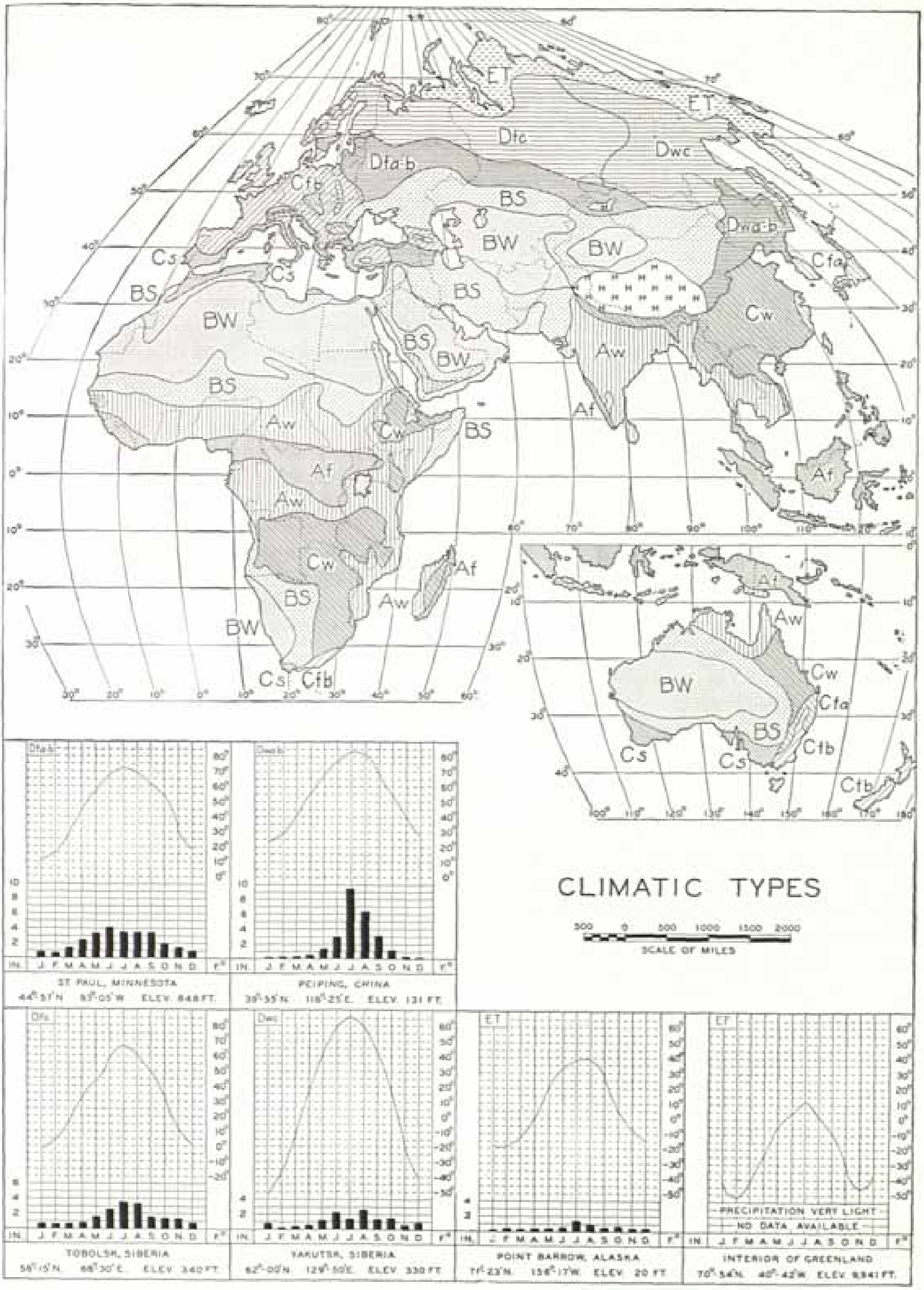


FIG. 439. Climatic types of the lands of the Eastern Hemisphere. (Modified from Köppen and Geiger.)

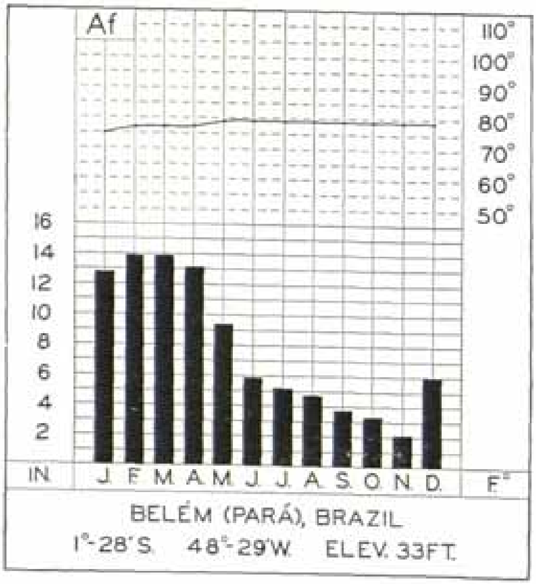


FIG. 440. Graph to show typical temperatures and precipitation for a place with the Af type of climate, Belem, Brazil.

sensible as well, are high, for humidity is like that in a greenhouse. Seasonal temperature range is slight, seldom more than 5 or 6 and sometimes less than 1 degree. Daily range is likewise small, but generally several times the annual. Precipitation is heavy, commonly 60 inches or more, well-distributed throughout the year, and all in the form of rain, which falls in heavy showers. Winds are light and variable in the doldrum belt; on trade-wind coasts, they are stronger and afford some relief from the oppressive heat. The graph for Singapore, Malaya, Fig. 438, and that for Belèm, Brazil, Fig. 440, show temperatures and precipitation for typical stations with this type of climate.

These conditions are favorable for growth of a luxuriant evergreen hardwood forest, its lower levels a tangle of lianas or vines, with many epiphytes such as tropical orchids attached to the branches of the trees wherever light comes through the dense canopy of leaves overhead. The forest floor is dark, without small, green plant growth. The animal life is characterized by many species of reptiles such as snakes; brightly colored birds like the parrot; monkeys and other tree-climbing forms, including carnivora such as the leopard; plus millions of insects. Where the forest cover breaks down along stream courses, the hippopotamus, crocodile, and other marsh and water denizens find conditions favorable.

Population is sparse and backward and limited to primitive hunting and agricultural tribes, except where civilized man intrudes his plantations, generally in trade-wind areas. Living conditions are so poor that regions with this type of climate are generally considered to be unfavorable for great future development.

Savanna or "Aw" Climate. On the poleward borders of the continuously well-watered equatorial regions of the tropics, and inland from their extensions into higher latitudes of the trade-wind regions, the dense forest growth is replaced by tall grass and scattered trees in the Savanna or "Aw" climate. Actual temperatures are still high, for this is an "A" type of climate, but sensible temperatures during the relatively long dry season are lower than in the "Af" type. Seasonal range is likewise greater, 8 to 15 degrees, because of the higher latitudes; and daily range, especially in the dry season, is considerable, sometimes as much as 30 degrees or more. Precipitation is not so heavy as in the tropical rain-forest, ordinarily 50 to 60 inches, but sometimes much less on the drier or poleward margins, fluctuating considerably in amount from year to year, but always with a definite seasonal maximum. All

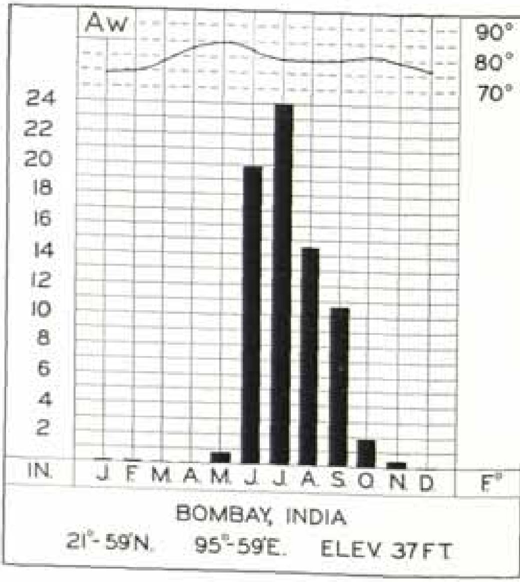


FIG. 441. Graph to show typical temperatures and precipitation for a place with the Aw type of climate, Bombay, India.

falls in the form of rain and in showers of considerable intensity. The graph for Cuiaba, Brazil, Fig. 438, and that for Bombay, India, Fig. 441, show temperatures and precipitations for stations with this type of climate.

These climatic conditions are favorable for the rank growth of tall grasses which spring up rapidly after the rains, only to become harsh, dry, and unpalatable for animals during the dry season. Such trees as occur are scattered, shed their leaves during the dry period, and are often protected by thorns. These are the conditions of the Llanos and Campos regions of South America and of the Sudan and veldt of Africa. This grassland vegetation furnishes food for millions of herbivorous animals, which in turn afford a food supply for numerous species of carnivora. This is the big-game country of the tropics.

These same elements of climate and vegetation which favor animal life make this the most desirable of the lowland regions in the tropics for man. In places, grazing affords the basis for support; again agriculture, particularly with irrigation to supplement the scanty rainfall of the winter months, enables effective production of cultivated crops. Thus these regions support dense native populations, which closes them effectively to white colonization, for whites cannot compete successfully with the present occupants because of their higher standards of living.

Mesothermal or "C" Climates. These are differentiated from other humid climates on the basis of temperatures, which are intermediate between those of the tropics and those of higher latitudes where winters are severe. Therefore, though the four seasons common in intermediate latitudes are distinguishable, they are not pronounced, for a minimum of 8 of the 12 months of the year have temperatures over 33.8° F., with at least one in which the thermometer reading drops below 64.4° F. In all, there are four subtypes: the "Cfa," "Cfb," "Cw," and "Cs." In the first two, "Cfa" and "Cfb," precipitation is well distributed throughout the year, indicated by the "f" in the letter designation; in the last two, the "w" indicates dry winters; the "s," dry summers. Inasmuch as the "C" climates extend through latitudes which reach from the margins of the tropics almost to the polar circles in some west-facing coastal areas, temperatures vary somewhat from subtype to subtype. This is indicated by the third letters, "a" and "b," in the first two of the subtypes. The "a" indicates a temperature of over 71.6° F. in the warmest month; the "b" one of less than 71.6° F. during all months of the year but at least 4 months with temperatures over 50° F.

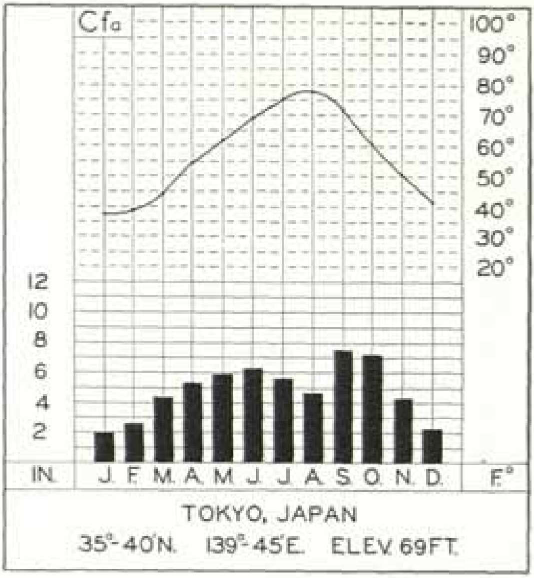


FIG. 442. Graph to show typical temperatures and precipitation for a place with the Cfa climate, Tokyo, Japan.

Humid Subtropical or "Cfa(Cw)" Climates. These types of climate occur on east-facing coasts on the poleward margins of the tropics, between 25 and 35 degrees of latitude. Because of this location, seasonal changes of temperature over the larger land masses such as Asia are sufficient to produce a monsoonal effect, which is generally reflected in distribution of precipitation to an extent that winters are relatively dry and the climate is designated as "Cw" in type. Elsewhere, this effect may be less pronounced, rainfall more uniformly distributed throughout the year, and the subtype becomes "Cfa." In either case, precipitation is ample, mostly rain, and temperatures are over 71.6° F. during the warmest month, with winters mild, as shown in the graphs for Hankow "(Cw)," and Washington, D. C. "(Cfa)," Fig. 438; Tokyo "(Cfa)" and Hanoi "(Cw)," Figs. 442 and 443.

This is a pleasant type of climate in several respects, for winters are sufficiently mild to present the opportunity for resort developments such as those of Florida and the Gulf Coast. Summers,

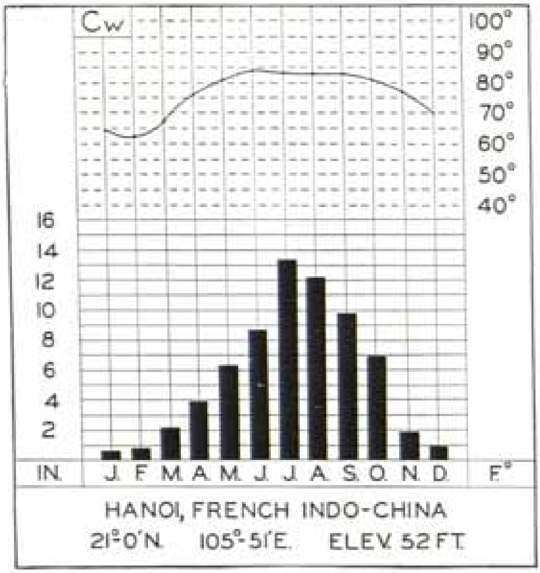


FIG. 443. Graph to show typical temperatures and precipitation for a place with the Cw type of climate, Hanoi, French Indo-China.

however, are not so agreeable, for the actual temperatures are rather high, and in association with a small daily range often not exceeding 10 to 15 degrees and high humidity, the heat is rather enervating. Thus Washington, a pleasant place to live during much of the year, is largely deserted by those able to leave during the summer months, when sensible temperatures are much higher than those recorded by the thermometer.

Forest growth, both hardwood and coniferous, with some scattered, culturally induced grassy openings, are characteristic of regions with this type of climate. Thus lumbering becomes an important industry in many such areas. Further, where topography and soils are suitable, the climate of both the "Cfa" and "Cw" types permits production of a great variety of crops, which tends to increase the profits from agriculture. Therefore areas with either of these two types of climate generally support large farm populations, some, like those of south China, among the densest in the world.

Mediterranean or "Cs" Climate. This dry-summer, subtropical climate derives its name from the fact that it is the characteristic type in lands which border the Mediterranean. In general, it occurs on west-facing coasts on the poleward margins of the tropics, roughly between 30 and 40 degrees of latitude. Because of the relatively low latitudes in which areas with this type of climate are located, winters, which have average temperatures of 45° to 55° F., are not cold. Neither are the summers, with temperatures of 70° to 80° F., excessively hot, though away from the marine influence along the coast extremes of heat and annual ranges of temperature are greater. Daily range of temperature in summer is normally considerable because of the dry air. Therefore nights are generally cool and comfortable, even though the heat in the sun at midday may be great. Precipitation is never heavy and generally light, seldom more than 30 and often 15 inches or less. It is poorly distributed because of the winter maximum, and, at or near sea level, practically all in the form of rain. The graph for Los Angeles, Fig. 438, and that for Athens, Fig. 444, show typical climatic conditions in the Mediterranean or "Cs" type of climate.

Because of limitations imposed by precipitation, forests are confined to elevations, but rainfall at and near sea level is ample for support of grassy vegetation and scattered trees and brushy growths in favored locations. Therefore a basis for grazing exists and it becomes an important industry in many Mediterranean areas. Agriculture, however, is handicapped by both the small

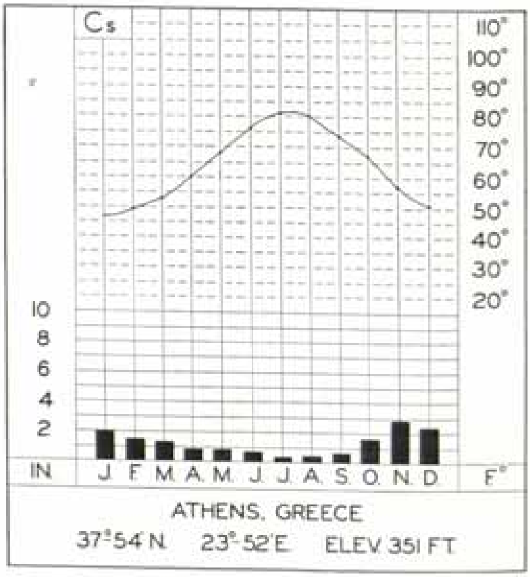


FIG. 444. Graph to show typical temperatures and precipitation for a place with the Cs type of climate, Athens, Greece.

amount and poor distribution of precipitation. Therefore it is normally limited to the growing of drought-resistant cereals, except where irrigation is possible. There, it tends to be of the garden type, with production of vegetables and fruit crops such as oranges and lemons. This is considered a very pleasant type of climate by many persons, for winters are mild, summers are not trying, and the sun shines most of the daylight period during the warm months. These conditions permit outdoor life most of the year. Therefore areas with this type of climate tend to develop an important tourist industry and to attract many permanent residents in the later years of their lives. Thus Los Angeles, for example, has come to have the reputation of being the "largest Iowa city in the United States."

Marine West Coast or "Cfb" Climate. This type of climate, characterized by a marine influence throughout the year, occurs in areas on west-facing coasts, located poleward with reference to regions which have the Mediterranean or "Cs" type of climate. During the winter, the winds from off the water keep temperatures relatively high, so that they are generally above freezing and commonly above 40° F.; during the summer months, the winds from over the water keep the land temperatures moderate and seldom in excess of 70° F. for any month. When temperatures around midday rise to 85° F. for several days in succession, indeed, the inhabitants complain of the heat, though nights, even then, are generally cool. This type of climate reaches into very high latitudes on west-facing coasts, for marine influence extends its modifying effect far to the north and south of the equator. Precipitation is well distributed throughout the year, but ordinarily not heavy at sea level, though increasing up to 80 inches or even more at elevations. Except at some distance above sea level, most of the precipitation is in the form of rain, and during the winter months there is much fog and mist. The general distribution of temperatures and precipitation for Seattle, where this type of climate is typically developed, is shown in the graph accompanying Fig. 438; and for Paris, France, in Fig. 445.

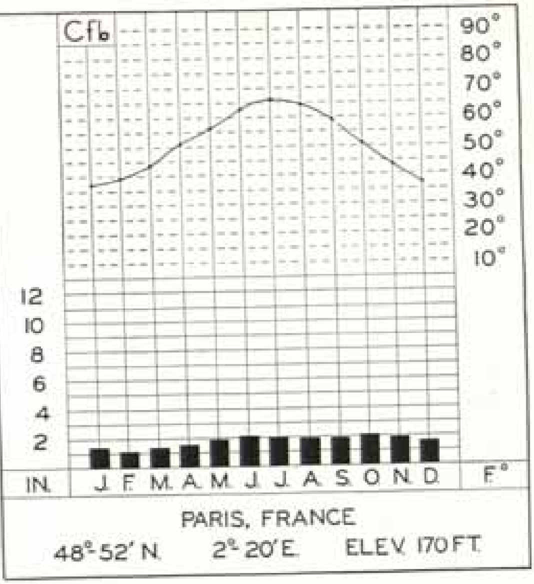


FIG. 445. Graph to show typical temperatures and precipitation for a place with the Cfb type of climate, Paris, France.

The native vegetation of areas with this type of climate is typically a dense coniferous forest, characterized by large trees and much undergrowth. Occasionally, as in northwestern Europe, hardwoods may also appear. This is one of the most valuable of the world's commercial forests and the basis for an important lumbering industry. When the timber has been cut, however, the land does not necessarily pass into agricultural use in the United States, for clearing is expensive and but few profitable crops can be grown because of the large number of days with cool, cloudy, and foggy weather. In northwestern Europe, where settlement is denser and pressure on the land is greater, much of the land has passed into use and an important dairy industry has developed. This is a very stimulating climate, the most effective of all in promoting human endeavor, according to Ellsworth Huntington. Whether this is a fact may be debatable, but it is certainly true that Europeans who live in areas with this type of climate show much enterprise and that they have made great progress, irrespective of whether climate was responsible for the development which has occurred.

Microthermal or "D" Climates. These climates are characterized by cold winters, often of great length and severity. In all, however, though a minimum of 3 months of each year have temperatures of less than 33.8° F., in at least one the temperature rises to between 50° and 64.4° F., so that growth of vegetation is possible. Four subtypes are recognized: the "Dfa(b)," "Dwa(b),"

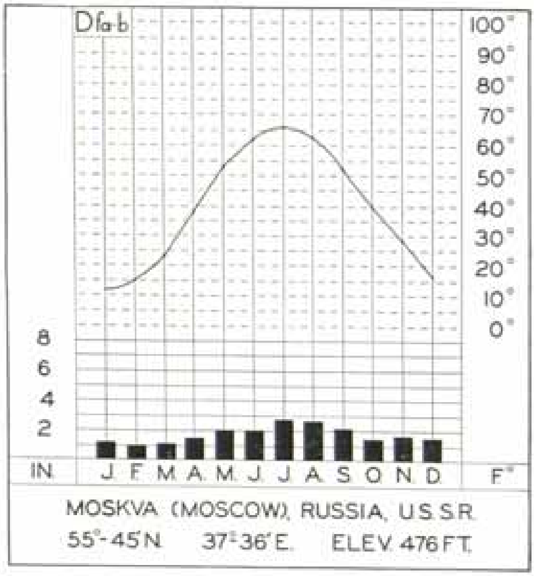


FIG. 446. Graph to show typical temperatures and precipitation for a place with the Dfa(b) type of climate, Moskva, U.S.S.R.

"Dfc," and "Dwc." These differ from one another in temperatures and precipitation distribution. In the subtypes in which the second letter is "f," precipitation is well distributed throughout the year; in those with the second letter "w," winters are dry. The third letter, "a," "b," or "c," refers to temperatures. Thus "a" indicates that the warmest month has a temperature of over 71.6° F.; the "b," that the temperature of the warmest month is under 71.6° F., but that at least 4 months have temperatures of more than 50° F.; the "c," that less than 4 months have temperatures over 50° F. With such temperatures, precipitation occurs in a great variety of forms, including snow, and is never very heavy, seldom exceeding 40 inches and often not in excess of 15. These facts are shown in the graphs accompanying Fig. 439, and in Figs. 446, 447, 448, and 449.

Humid Continental or "Dfa(b)" and "Dwa(b)" Climates. These types occur in continental interiors and on east-facing coasts, on the poleward margins of areas with "C" climates. They are characterized by normally sufficient, though sometimes erratic rainfall, associated with cyclonic control, falling in a great variety of forms, and with variable intensity. Winters are cold and both long and severe on the poleward margins of the "Dfa" and "Dwa," and everywhere in the "Dfb" and "Dwb" types, with snow covering the ground for several months each year. These conditions are shown in the graphs for St. Paul, "Dfa(b)"; and Peiping, "Dwa(b)," which accompany Fig. 439. They are also shown in the graphs for Moskva, "Dfa(b)," Fig. 446; and Harbin, "Dwa(b)," Fig. 447.

These climates favor forest growth, coniferous in character on the poleward margins and of slight importance in the higher latitudes, but of great value where the climate is less severe. In the "Dwa(b)" types, the forest is generally limited in extent for the dry season may be long, but in the "Dfc," conifers, and in the "Dfa" climate, valuable hardwoods, constitute a resource of great importance. When cleared, moreover, the land with a cover of hardwood forest generally passes into profitable agricultural use, for climate permits growth of many cereals and other crops and development of the dairy industry. In certain interstream areas with the "Dfa" climate in the United States, prairie replaces the forest, under which grassland cover extremely productive soils develop. These find agricultural use similar to that of the better soils of hardwood forest areas. Regions with the "Dfa(b)" and "Dwa(b)" climates are in general areas of more

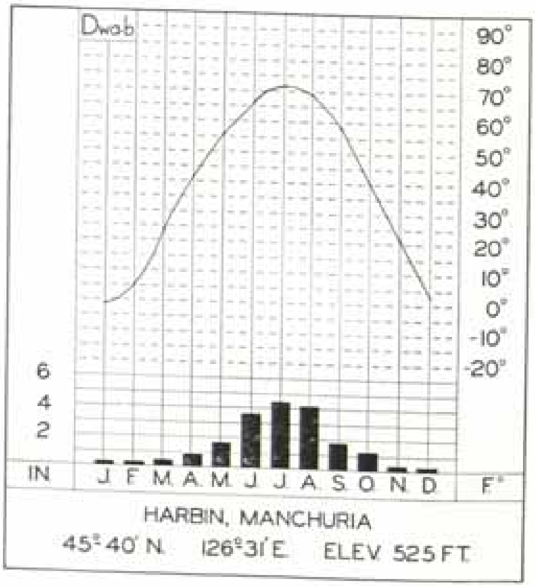


FIG. 447. Graph to show typical temperatures and precipitation for a place with the Dwa(b) type of climate, Harbin, Manchuria.

than average opportunity and normally support energetic, progressive, and considerable populations which have often attained a high degree of industrial development in Occidental regions.

Subpolar or "Dfc" and "Dwc" Climates. Areas with subpolar climates are confined to the interiors of the great land masses and their borders which front on polar seas, in latitudes of from 50° to 60°. On their polar margins, they merge into areas with Polar or "E" types of climate; on their equatorward sides, into those with Humid Continental, "Dfa(b)" and "Dwa(b)," or even "B" types, where precipitation is less. These are climatic types of the lands of the Northern rather than the Southern Hemisphere, because large land masses are lacking in the higher middle latitudes south of the equator.

Temperatures are low much of the year, the third term of the letter designation, or "c," indicating that there are less than 4 months of the year with temperatures over 50° F. During the winter, temperatures for January may average as low as −60° F., but during the short summer they may average 60° F. or more. At midday, maximums of 80° F. are common and of 90° F. not unknown, for summer days are long and the sun rises considerably above the horizon at noon in these higher latitudes. At the 65th parallel, for example, the average day during the month of June has 22.1 hours of sunlight, with the apparent period of daylight still further prolonged by twilight. No other types of climate show so great a contrast between summer and winter temperatures. The temperatures and precipitations for typical stations with these types of climate are shown by graphs for Tobolsk, "Dfc," and Yakutsk, "Dwc," which accompany Fig. 439; and by Figs. 448 and 449, for Tomsk and Okhotsk, both in Siberia, the former having a "Dfc," the latter a "Dwc" type of climate. The extremely low temperatures of the winter months cause frost to penetrate to such great depths that the soils and the underlying parent material are perpetually frozen at depths, thawing but a few inches near the surface during the short summers.

Precipitation is light, varying from less than 15 to not to exceed 20 inches, and falling in larger part during the summer months, particularly in the "Dwc" type, with a less pronounced seasonal distribution in the "Dfc" climate. Such precipitation as occurs during the winter months is in the form of snow, but the air is so cold that its absolute humidity is low and snowfall is light. The dryness of the air during the winter is advantageous in that the cold is less trying than it would be were the humidity high. Because of the

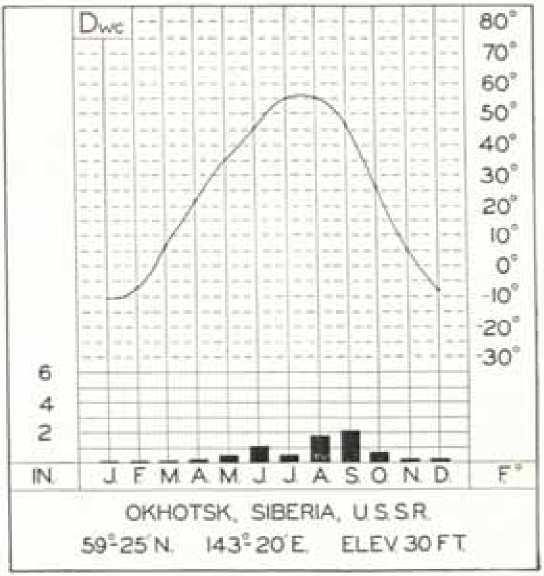


Fig. 449. Graph to show typical temperatures and precipitation for a place with the Dwc type of climate, Okhotsk, Siberia.

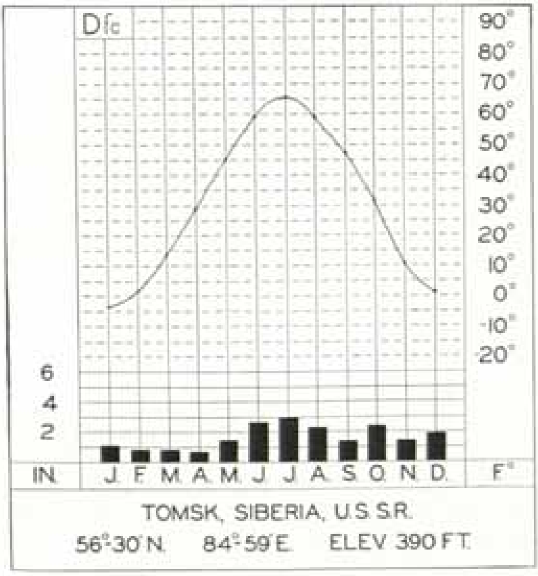


Fig. 448. Graph to show typical temperatures and precipitation for a place with the Dfc type of climate, Tomsk, Siberia.

low temperatures, the small amount of rainfall is sufficient to support vegetation and even forest, the "taiga" of Siberia, in the more favored portions. However, areas with these types of climate are greatly handicapped and support but few inhabitants, many just emerging from the Stone Age in development, for limited opportunity prevents a dense population.

Polar or "ET" and "EF" Climates. These are climates of polar areas and their margins, where daylight may be continuous for weeks in summer and nights correspondingly long in winter. However, though light for so long in summer, the temperature of the warmest month never exceeds 50° F., indicated by the letter "E" in the names of the subtypes, and winters are both long and bitterly cold. Such temperatures prohibit forest growth. Therefore the poleward boundary of forests separates the Polar or "E" from the Microthermal or "D" climates.

Tundra or "ET" Climate. Areas with an "ET" climate lie between the regions of perpetual snow and ice of the areas which border the poles and sub-Arctic areas with tree growth. Equatorward, the temperature of the warmest month rises to 50° F.; on the polar margin, it drops to 32° F. This is essentially a land climate of the Northern Hemisphere for, in the Antarctic, summer months over the land are almost everywhere too cool for this type. The most extensive land areas with this climate are located in northern North America and Eurasia, bordering the polar seas.

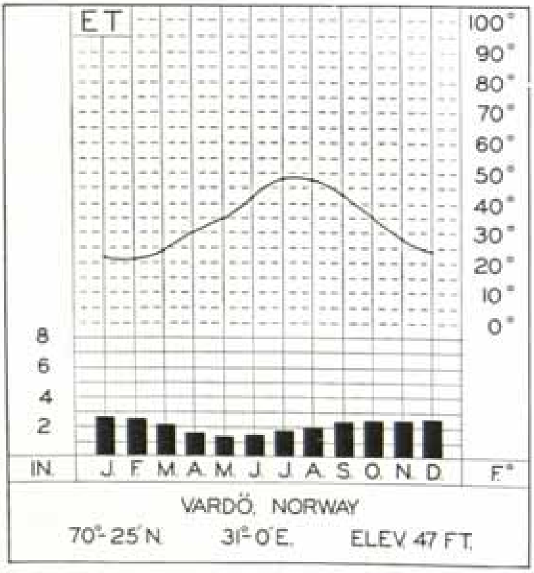


Fig. 450. Graph to show typical temperatures and precipitation for a place with the ET type of climate, Vardö, Norway.

At no time of the year is it warm, for not more than 2 to 4 months have average temperatures above freezing and frost may occur any month of the year. Daily range of temperature is relatively small because of the long periods of daylight and darkness which, however, accentuate the annual range. Poor natural drainage, plus perpetually frozen subsoils, tend to create bog conditions which favor the breeding of mosquitoes and thus make life insufferable for both man and his animals during the warmer months. During the winters, temperatures of −40° F. and lower cause equally great discomfort. Precipitation is seldom in excess of 10 to 12 inches and often much less, but evaporation is low, hence these amounts suffice for vegetation. Some of this falls as rain during the warmer months, but that of winter is light snow which is blown by the wind so that much of the land surface is left bare. For a representation of these climatic conditions, see the graph for Point Barrow, Fig. 439; and for Vardö, Norway, Fig. 450. The weather is generally disagreeable, for skies are often cloudy; fogs are prevalent; and snow may fall, even in summer. In addition, soils are either wet or frozen. These are not favorable conditions for man, therefore areas with this type of climate support but sparse populations.

Polar or "EF" Climate. This climate is developed over the great continental glaciers which cover Greenland and the Antarctic continent. Though only fragmentary data are available, average temperatures for the year are certainly lower than those of any other type of climate and Antarctica has the coldest known summers, though not the lowest winter temperatures. Even less is known concerning precipitation than temperatures, though it is everywhere light and for the most part, hard, sandlike, wind-driven snow. In fact, it is supposed by some that surface wind scour is a very important process in movement of snow from the interior to marginal locations, where iceberg discharge occurs. See Fig. 438 for a graph of climatic conditions in the interior of Greenland, and Fig. 451 for one of conditions in Antarctica. Areas with this type of climate are devoid of all plant and animal life and at present support no populations.

Dry or "B" Climates. Regions with these climates suffer from precipitation deficiency, for during normal years the possible evaporation exceeds the actual precipitation. Therefore soils are commonly dry except for a few inches near the surface; runoff occurs only during and for a short period after rains; and stream beds are dry most of the time, except for those of rivers which do not originate in but only cross areas with "B" climates. This is because ground-water supply or stored rainfall is not ample to maintain continuous flow. The exact amount of rain necessary to assure this relationship between precipitation and evaporation is variable, particularly with seasonal distribution and temperature. Thus the boundary between humid and dry climates is fixed by both precipitation and temperature factors.

These dry climates occur in a great variety of latitudes, but in general in continental interiors, far from the ocean, the eventual source of all moisture; where mountain barriers arrest moisture-laden winds; and on lee coasts, where winds are from over the land and dry rather than from over the ocean and moisture-laden.

Precipitation is always light, variable in amount from year to year, often irregularly distributed within the year, and commonly torrential in character. Seldom does it exceed 20 inches in amount, and it is often much less. Though no absolutely rainless areas are known on the earth's surface, some such as the Atacama Desert of northern Chile, which in certain places receives as little as 0.02 inches yearly, are practically without rain, except for rare, heavy showers, sometimes years apart. With such small amounts of rainfall, vegetation is always sparse and drought-resistant in type. Within the "B" climates there is sufficient variation is precipitation to ensure distinct differences in the vegetation cover, and thus either steppe or desert. Therefore two subtypes will be recognized: the Steppe or "BS," and the Desert or "BW" type. In these letter designations, the "S" stands for Steppe; the "W" for Wüste," the German word meaning "desert."

Temperatures likewise vary, but with latitude. Thus in higher latitudes, they are low; elsewhere, high. Sometimes there is great and sometimes moderate seasonal range, dependent principally on distance from the equator, with that from the ocean likewise of importance. Daily range is everywhere great, for the dry air, generally cloudless sky, and partially bare ground facilitate both rapid heating by day and cooling by night. Therefore temperatures may rise to 100° F. or more in the heat of the day and fall to freezing or below during the night. Because of variation in temperature with latitude, the "BS" climate may be subdivided into the "BSh" and the "BSK"; and the "BW" into the "BWh" and "BWk" types, the "h" meaning "heiss" or hot; and the "k," "kalt" or cold.

Steppe or "BS" Climates. Within the tropics, these are climates of areas marginally located with reference to the trade winds and subtropical highs; in intermediate latitudes, they occur in continental interiors; where mountain barriers shut off rain-bearing winds; or on lee coasts toward which winds do not blow from over water with sufficient regularity to supply ample rainfall. On their drier margins, they grade into deserts; on their wetter, into areas with humid climates, "A," "C," or "D."

Precipitation is everywhere limited in amount, variable with latitude but seldom as much as 25 and sometimes less than 10 inches. It is always erratic in occurrence, often of many forms, and of differing intensity. Temperatures vary similarly, both in respect to the actual and seasonal range, but the daily range is always great and sensible temperatures are lower than those rec-

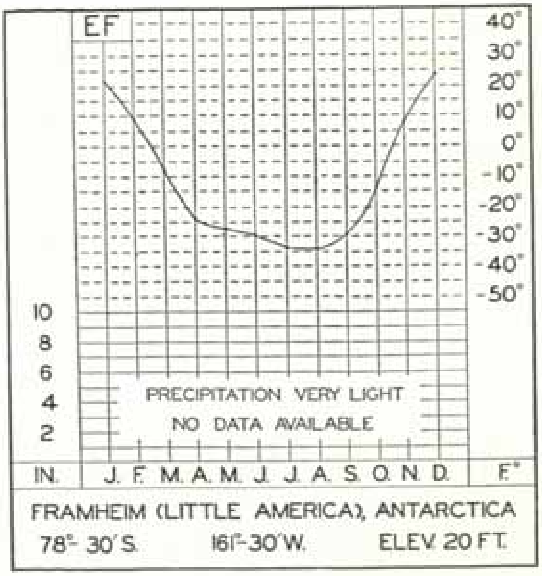


FIG. 451. Graph to show typical temperatures and precipitation for a place with the EF type of climate, Framheim (Little America), Antarctica.

orded by the thermometer. This makes them more tolerable for man. Most of these facts are shown in the graph for Baghdad, Fig. 438, and by that for Urga, Fig. 452.

The vegetation cover is typically one of short grasses, dependent on moisture in the top few inches of the soil. Nowhere is the cover continuous; occasionally it is much interrupted. Such grasslands often have excellent soils, but the limited precipitation makes agriculture hazardous. Therefore areas with this type of climate offer more opportunity for grazing than for crop production, except where irrigation is possible.

Desert or "BW" Climates. In the tropics, these are climates of the heart of regions of trade winds and subtropical highs, lying for the most part between the parallels of 18 and 25 degrees, both north and south of the equator. In higher latitudes, areas with this type of climate are discontinuous and scattered, their exact location and extent being largely dependent on the existence of mountain barriers which arrest moisture-bearing winds.

Temperatures vary with latitude. In the tropics, they may rise to 120° F. or more at midday; farther from the equator, almost equally high in the heat of the day, for this type of climate has the highest temperatures of record. Nights are

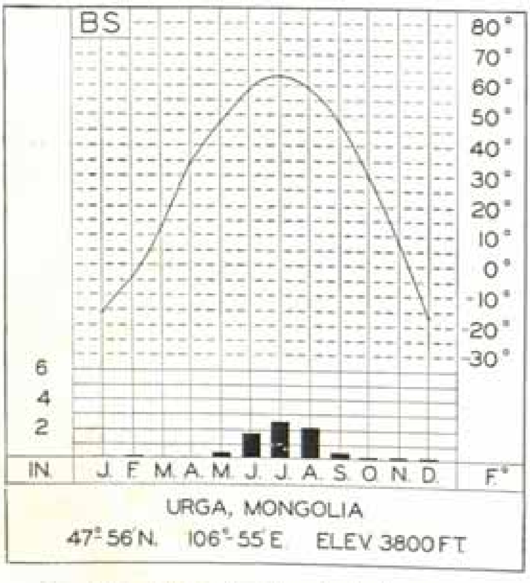


FIG. 452. Graph to show typical temperatures and precipitation for a place with the BS type of climate, Urga, Mongolia.

cool, however, for radiation is rapid, therefore daily range is great. Because of the dry air, sensible temperatures are lower than those recorded by the thermometer. Annual range is greater than in better watered areas with comparable latitudes in the tropics, sometimes as much as 20 to 30 degrees, for this is one climate of the lower latitudes where the annual may exceed the daily range. In the higher latitudes, this is always true, for the annual range may be as much as 60 degrees or more. These conditions are shown for Aswan, on the graph accompanying Fig. 438, and by Fig. 453 for Iquique, Chile.

Precipitation is light, probably seldom exceeding 15 to 18 inches and generally much less. Over much of the Sahara, for example, it averages less than 5 inches for the year. In the lower latitudes, these are the most nearly rainless areas in the world for, in certain deserts, rain may not fall for a period of several years. Rains are generally local and torrential in type, and often destructive in character. In extreme cases, according to Kendrew, 34 inches of water have been known to fall within 2 days in northwestern India, where the normal annual rainfall is only 5 inches.

These are conditions favorable for neither plant nor animal life and therefore not for man. This type of climate, indeed, shares with the "EF" type the distinction of being one of the two most unfavorable known. Therefore population is everywhere sparse and backward, except where irrigation is possible.

Highland or "H" Climates. There is no single highland climate but a multiplicity of types, varying with both latitude and altitude. Even within a given highland there are often several climates, resulting from differences in altitude and exposure. Because of this fact, no graph accompanies the climatic maps, Figs. 438 and 439, though the accompanying graph, Fig. 454, shows the conditions for one station, Quito, Ecuador. All these types, however, possess certain common characteristics and, in this general and simplified treatment of climates, consideration will be limited to them.

Because of the thin and generally clear air at considerable elevations, a large percentage of the insolation reaches the earth's surface, which causes surprisingly high day temperatures in the sun and correspondingly high soil temperatures. These climates have therefore been described as ones of "cool shade and hot sun," for air tem-

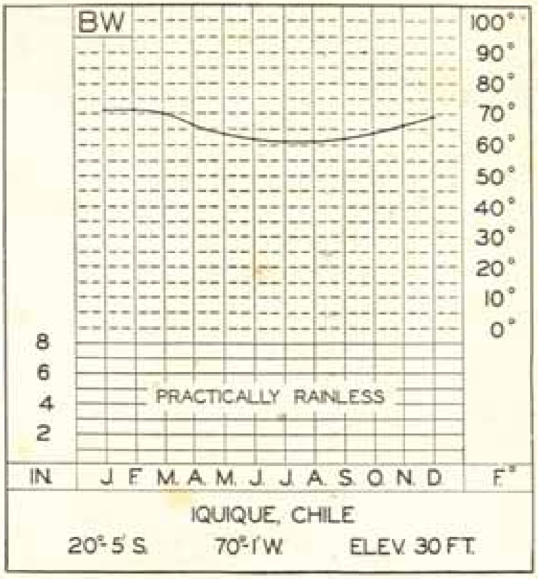


Fig. 453. Graph to show typical temperatures and precipitation for a place with the BW type of climate, Iquique, Chile.

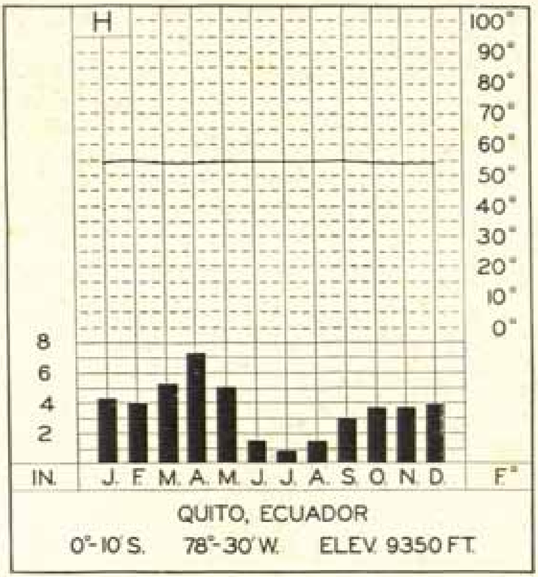


Fig. 454. Graph to show climatic conditions at Quiro, Ecuador, a place with an "H" type of climate.

peratures as such are low. Radiation is rapid at night, however, hence it is cool to cold after sunset and the daily range of temperature is considerable. Contrasts between the weather of day and night are therefore much more marked than at lesser elevations. The seasonal range of temperature varies with latitude, increasing from virtually 0° at or near the equator to as much as 60° or more in intermediate and higher latitudes. Therefore highlands of the higher latitudes are markedly different from these nearer the equator with respect to climate.

Precipitation increases in amount in highlands up to elevations of from 4000 to 7000 feet, above which it becomes less. In addition, windward slopes, toward which winds blow, are normally well watered; lee, or the opposite slopes, have only light rainfall. Thus there are marked variations in precipitation within short horizontal distances, resulting from differences in either elevation or exposure. Though winds are commonly strong on exposed slopes, there are few localities so well protected as mountain valleys. Because of the great relief, however, local winds such as the chinook or foehn frequently develop on the slopes. These are often of great local importance.

Except in the tropics, highland climates possess few advantages to offset the handicaps they impose, for they limit land use without compensating advantage. The thin air of great elevations also makes physical exertion difficult to impossible. In general, therefore, highlands of considerable to great elevations support but sparse populations, especially in the higher latitudes.

Much more detailed descriptions of the 15 types of climate recognized and described on the preceding pages, as well as additional types and subdivisions, can be found in the selected references listed at the end of the chapter.

QUESTIONS AND EXERCISES

1. Why is the objective of classification of climates defeated by recognition of too large a number of types? What are the advantages of the Köppen system of climatic classification?

2. Into what three major subdivisions may climates be divided? What is the distinction between these classes? What fourth type of climates is recognized in the classification in the text?

3. How are the "A" climates differentiated from other humid climates? What are the types of "A" climates? On what basis is this division made?
4. State the climatic characteristics of the "Af" type of climate in respect to temperatures, precipitation, and winds. Where does this type of climate occur? In what respects is it unfavorable for man?
5. Where does the "Aw" or Savanna climate occur? In what respects does it differ from the "Af" climate in temperatures and precipitation? During which season of the year are sensible temperatures lowest in this type of climate? Why? What is the density of population in areas with this type of climate? Why?
6. State the general characteristics and the subdivisions of the "C" climates.
7. In what respects do the "Cw" and "Cfa" climates differ? In what respects are they alike? Why is there a summer maximum of precipitation in the "Cw" climate? How does this affect the character of the native vegetation?
8. What are the dominant occupations of populations in areas with "Cw" and "Cfa" climates?
9. Where does the "Cs" type of climate occur? Why are winters mild in this type of climate? How does the precipitation of the "Cs" climate affect the character of human occupancy? Why does the resort business tend to develop in areas with this type of climate?
10. Where is the "Cfb" climate located with reference to the "Cs" type? Why does it extend into high latitudes? Where? Describe the climatic conditions, the native vegetation, and their effect on agricultural use of the land.
11. What are the characteristics of the "D" climates? Where are they found? What are the subdivisions and the basis for each?
12. What are the differences between the "Dfa" and "Dfb" types in respect to climate and native vegetation?
13. What is the location of areas with subpolar climates? Why are winter temperatures severe in these climatic types? Why are summer temperatures so high? From what handicaps do areas with such climates suffer?
14. What are the two Polar climates? How do they differ? Why are they land climates of the Northern rather than the Southern Hemisphere? State the climatic characteristics of the two polar climates.
15. How are the dry or "B" climates differentiated from the humid types? What fixes the boundary between the dry and humid types of climate? What are the general characteristics of the "B" climates? What are the subdivisions of the "B" climates?
16. Locate the areas where Steppe or "BS" climates occur. Into what types do they grade on their drier margins? What occupation dominates in Steppe climates?
17. Where do the Desert or "BW" climates occur? What are the two subtypes of Desert climate? Describe the temperature conditions of "BW" climates.
18. Why is there a multiplicity of climates in highlands? What causes physical exertion to be difficult at great altitudes? What are the common characteristics of all highland climates? In what latitudes, if any, do highland climates offer advantages for man's occupation?

SELECTED REFERENCES

Trewartha, G. T., *An Introduction to Weather and Climate*, McGraw-Hill Book Company, Inc., New York, 1943, Chaps. VI, VII, VIII, IX, X, and Appendix A, with map.

Chapters VI to X, inclusive, contain extended description and discussion of individual climatic types; Appendix A, with the map, a statement of the Köppen system of climates in summary form. These should be adequate to supplement the text consideration of climatic types, if additional treatment of climates is desired.

Chapter Fifty-One

WEATHER PREDICTION

Weather Forecasting. It is possible for an experienced observer to make helpful deductions as to probable weather changes from a careful study of local conditions only, but effective prediction of the weather necessitates assembly of meteorological reports from a well-organized network of many well-distributed stations. Although long empirical in character and still far from perfection, weather forecasting has profited from recent developments to achieve much greater accuracy than was possible in the past. Nevertheless, it still "continues to be a combination of physical reasoning with the practical experience of the synoptic charts."

Observational Data. The weather forecasts of the United States Weather Bureau are based on data collected at some 600 stations in this country, with about 60 per cent of that number located along the lines of civil airways, supplemented by reports from other countries of the Americas, and from ships in adjacent waters. Hourly observations are taken at the airway stations; at those off the airways, at 6-hour intervals, and in a few cases, every 3 hours. Surface temperature, pressure, wind, and humidity data are collected at all stations; upper-air wind observations at 140 by means of pilot balloons; and at 30, reports on upper-air temperature, pressure, and humidity are secured. These data are relayed by various means to the forecast stations and to Washington for analysis and charting.

Charts and Graphs. After assembly of the data from the stations at the forecast centers, including Washington, they are plotted on maps, the principal one, the only one considered in this treatment of weather prediction, and the one of most interest to the average person being the synoptic chart or the weather map. On the map prepared at Washington, the data are recorded for each station as shown in the station model, Fig. 455, and in abbreviated form in Fig. 115, a simplified weather map for June 14, 1945.

Cyclones, Anticyclones, and Air Masses. Cyclones or areas of low pressure, with their spirally inward flow of air, and anticyclones, or areas of high pressure, with the surface air moving spirally outward from their centers, are made up of both cold and warm air masses. Thus the eastern part of an anticyclone and the western part of the adjoining cyclone consist of a unit of cold air, with temperatures low or falling and pressures rising. By contrast, in the western part of a high-pressure area and the contiguous eastern portion of one of low pressure, temperatures are high or rising and pressures are falling. Both highs and lows vary in form and likewise in character, though within fixed limits.

Fronts and Air Masses. When air remains over an extensive area for some time, it acquires temperatures and humidities characteristic of that region. Thus it becomes warm and humid over the Gulf of Mexico, but cold and dry over the interior of Canada during the winter months, not only at the surface but, after a few days, for some distance aloft. On the surface of the earth, these air masses meet along a line, and vertically, along a plane known as a "front." According to the generally accepted belief at present, a cyclone consists of two essentially different air masses, one cold, the other warm, separated by a fairly distinct boundary line through the cyclonic center. On the eastern margin of the low, where cold air is being displaced by warm air, the plane of contact is known as the "warm front"; on the opposite margin of the low, where cold air replaces warm air, as the "cold front."

Under this view of the structure of cyclones,

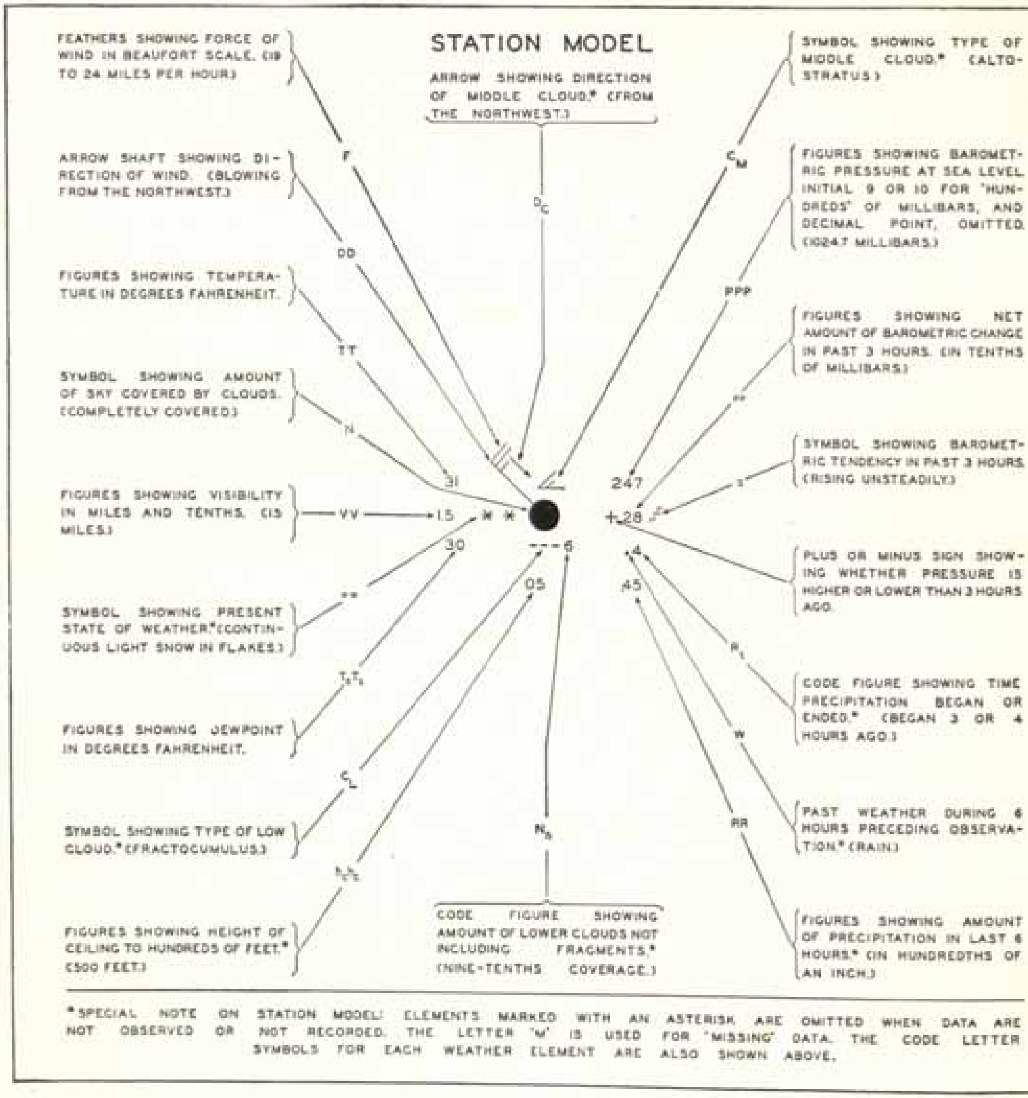


FIG. 455. Station model. (After the U. S. Weather Bureau.)

they result from the importation of large masses of cold air from the higher latitudes and of warm air from the tropics, and they develop along a line of discontinuity between the cold polar and warm tropical air, wherever a wave or bend forms along the line of contact of these air masses.

Precipitation may occur along either the warm front, where the warm air is cooled as it overruns the colder surface air to the east; or along the cold front, where warm surface air is forced aloft by inflowing colder air from the west. (See Fig. 111.) Between the two fronts, the air is warm; skies are relatively clear except for scattered cumulus clouds; showers are local and of convectional character; and the sun shines most of the daylight period.

Air Mass Analysis. "Air mass analysis" is analysis of temperature, moisture, and other meteorological conditions of the air, including frontal structures and their bearing on stability, in the areas of observation. Such studies are valuable in weather prediction, though it is still true that "the ability to forecast weather comes as much from experience as from study."

Preparing the Synoptic Chart or the Weather Map. After recording the data for each station on the chart as described earlier, the next step is the plotting of the isotherms or lines of equal temperature, and of the isobars or lines of equal pressure. This is followed by locating the cold and warm fronts, largely on the basis of surface temperature, wind, and dew-point discontinuities, together with pressure characteristics and tendencies. When marked discontinuities are evident, they locate the fronts without difficulty; otherwise, pressure tendencies serve to fix their position. The following step is to estimate the future movement of the fronts. This is based on their type and previous movement, plus general rules of an empirical character formulated from experience. It is likewise desirable to forecast the development and changes in intensity of fronts and highs and lows, though this is normally difficult.

These facts concerning the air masses and fronts are recorded on the weather map by the use of appropriate symbols. Fig. 115 shows a completed map for June 14, 1945, a reproduction of the map for that date as issued by the Washington station, except that not all the station data are shown, as in the station model, Fig. 455.

Predicting the Weather. After this preliminary analysis, the weather forecaster is in a position to make a prediction of the probable weather for a few hours in advance with a reasonable degree of accuracy.

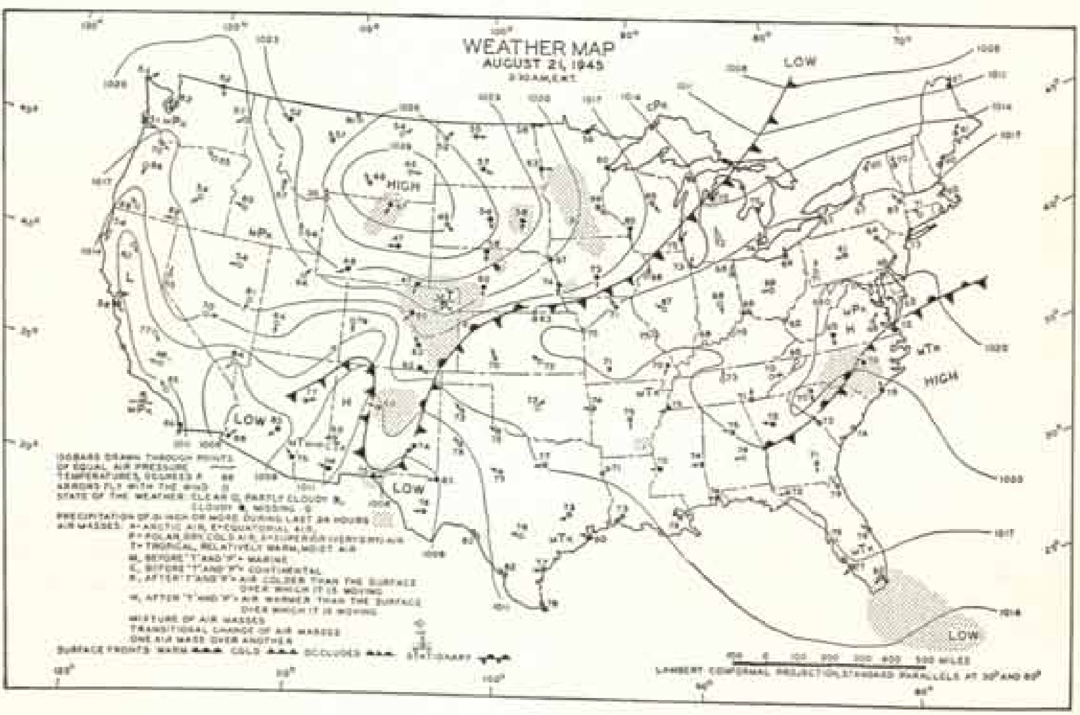
Forecasts based on 1:30 A.M., Eastern Standard Time observations are distributed daily by radio between 5:00 and 7:00 A.M. Observations made at this time likewise supplied the data for the weather map, Fig. 115, and for the four weather maps shown in Fig. 456. A second set of observations at 7:30 A.M., Eastern Standard Time, is used in making the weather prediction issued about 9:30 A.M. At airway stations, predictions are issued at intervals of 6 hours. For stations on air lines, the forecast is for 8 hours in advance; for other stations, the prediction is normally for a 24- to 36-hour period.

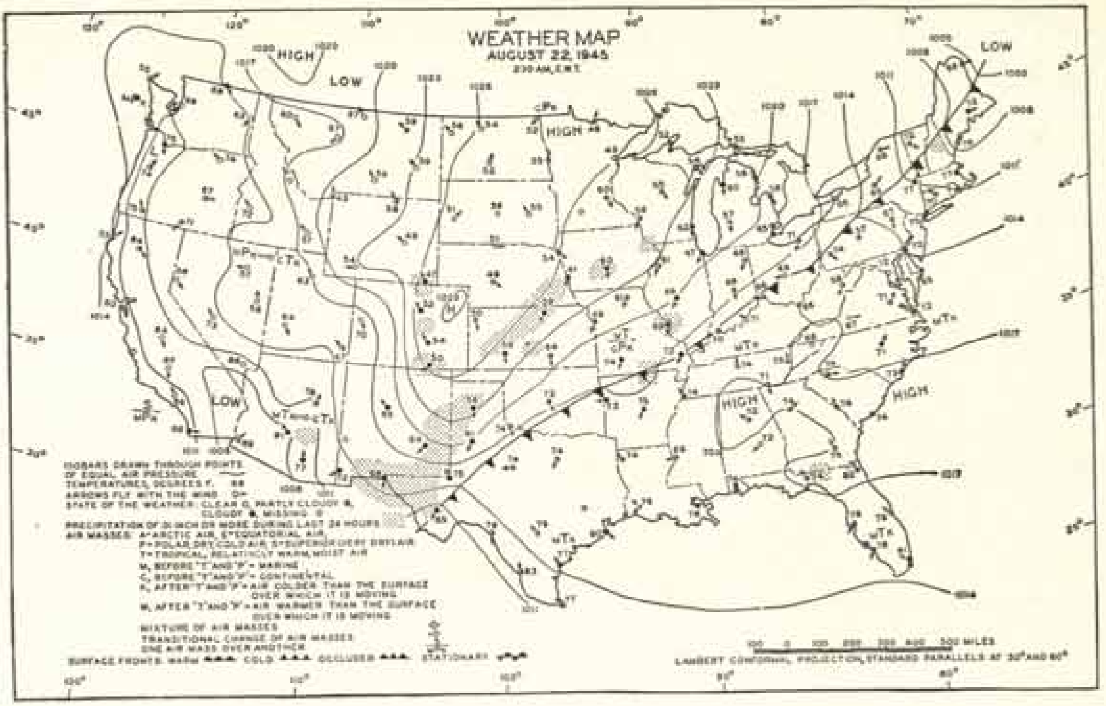
It is apparent that forecasting wind direction and velocity necessitates prediction of movement of highs and lows and their attendant discontinuities. Further, ability to forecast the winds determines the possibility of predicting temperatures, which are dependent on winds. Prediction of precipitation is much more difficult than forecasting winds and temperatures. In some cases, indeed, it is impossible to be certain whether precipitation will occur and, even if it does, it may be scattered. In view of the fact that the average person is interested in weather prediction largely with respect to rainfall and protection against it, this may be why the forecaster is often referred to as "Old Man Probabilities."

Weather Predictions for Longer Periods. To meet the insistent demand of business, industry, and commerce for predictions of more than 24 hours in length, the United States Weather Bureau has, since 1940, issued twice-a-week forecasts, one on Tuesday, the second on Saturday of each week. The first covers the period from Wednesday to Saturday; the second, from Saturday to Wednesday. These forecasts attempt to predict whether temperatures and pressures will be normal, above, or below the average; and the order in which cold, warm, and rainy spells will occur. It will be noted that these predictions are general in character and, if this is necessary for periods as short as less than a week, it follows that, for the present at least, seasonal forecasts of value are impossible.

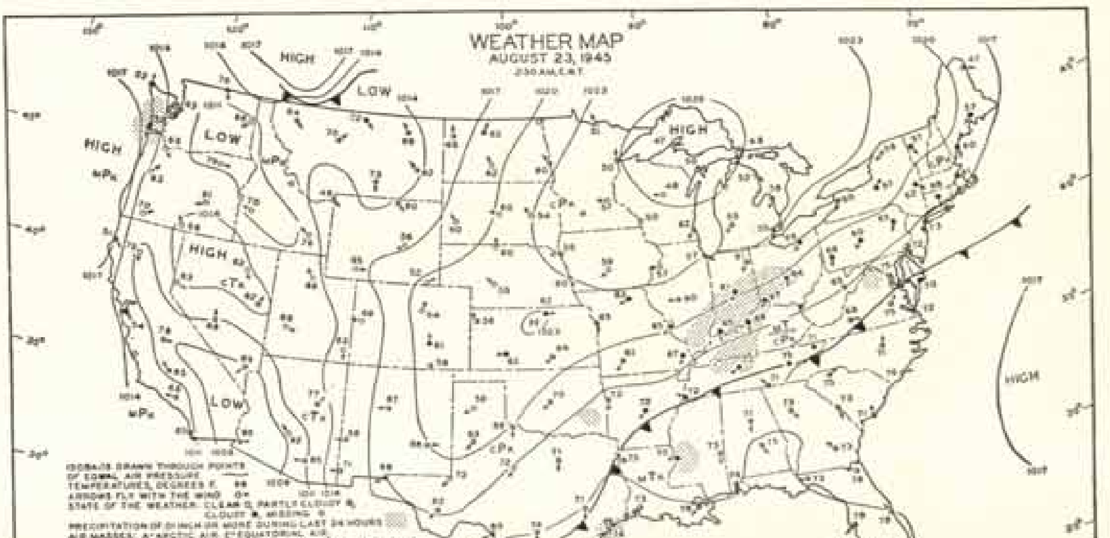
Values of Weather Forecasts. Weather forecasts have already demonstrated their practical value. In agriculture, they enable the grower to protect against frost damage; they notify the shipper of perishable commodities as to the temperatures to be expected; they warn the mariner of storms and their courses; they alone make navigation of the air safe; they serve to make planning of successful military campaigns a possibility in time of war. If prediction of the weather for long periods of time in advance ever becomes possible, and this may occur, the value of weather forecasting will be even greater, for then intelligent long-range planning of agricultural and other production will become a possibility rather than the dream of visionaries.

FIG. 456. Four days of summer weather in the United States, shown by the weather maps for August 20 to





August 23, 1945, inclusive. (After the weather maps of the U.S. Weather Bureau, issued at Washington, D.C.)



QUESTIONS AND EXERCISES

1. What observational data are collected as a basis for weather forecasting? Where are the stations at which these data are collected located? Why? At what intervals are observations made? How do observations taken differ at various stations?
2. What is the principal chart made by the United States Weather Bureau on the basis of data collected at the stations of observation? How is this chart made?
3. What types of air masses make up a cyclone? What is meant by a "front"? Name the two fronts of a cyclone and state their location with reference to the low-pressure area. How are cyclones supposed to develop?
4. Where may precipitation develop in a cyclone? Why? In what part of the cyclone are skies commonly clear and the weather fair?
5. How are the fronts located? Why is it desirable to be able to predict the development and changes of intensity of fronts in weather forecasting?
6. Why is it necessary to forecast the winds to predict the weather? Why is it more difficult to predict precipitation than temperature changes?
7. What daily predictions are issued by the United States Weather Bureau? For how long a time in advance are these predictions made?
8. What predictions, other than those for a 24- to 36-hour period in advance, are issued by the United States Weather Bureau? What aspects of the weather are covered by these longer range predictions?
9. What are some of the practical values of present-day weather predictions to agriculture, transportation, commerce, and industry? How are such predictions of value in times of war? Illustrate by examples from the late war.
10. Are long-range, seasonal predictions of the weather possible at present? Of what benefit would such predictions be to man?

SELECTED REFERENCES

Weightman, R. H., "Forecasting from Synoptic Weather Charts," *Miscellaneous Publication* 236, U. S. Department of Agriculture, Washington, rev., June, 1940.

In view of the present widespread popular interest which attaches to information about the weather to be expected, this pamphlet of 52 pages was prepared to meet the needs of the average person interested in weather forecasting. The student should find it easy to read and it will, as well, supplement the somewhat limited text treatment effectively.

Chapter Fifty-Two

AMERICAN SOIL CLASSIFICATION

Variability of Soils. Soils are of such great diversity that more than 1500 kinds have been identified and described and an even larger number will eventually be recognized. Fortunately, these fall into a relatively small number of groups. Therefore it is not difficult to obtain a general knowledge of them and their relationships, though it would involve much effort to keep the characteristics of each individual soil type clearly in mind.

Soil Classification. Satisfactory classification of soils is a relatively recent development, despite the fact they have for so long found use in agriculture, probably the most important of man's economic activities. In part, this has been because their nature was unknown until recently. Because of this, the earlier classifications were genetic, or based on origin, either with reference to the parent material or the action of soil-forming agencies. Today, by contrast, our soils are commonly classified according to their individual characteristics, not on the basis of factors which affect or produce them. This is sometimes known as the "attributive" system.

In this system, some selection of critical characteristics is necessary. In practice, therefore, those utilized are color, texture, chemical character, and degree of maturity. This last characteristic is measured by the extent of change in the cycle of development which is typical of soils, as shown in the series of layers which make up the "profile." Thus soils are classed as young, mature, and old, dependent on the total change undergone, as registered in the soil profile.

Classification may also take drainage, structure, consistency, and other factors into account, but chemical classes, particularly with reference to lime accumulation, are most important. According to Marbut, mature soils may be divided on this basis into "lime-accumulating" and "non-lime-accumulating" types. The former are known as "pedocals," the latter as "pedalfers." This classification enjoys the advantage of possessing a regional basis as well.

Pedalfers. These soil types occur in the eastern half of the United States and in numerous scattered tracts farther west. All these areas have normally ample rainfall and, except in the regions of tall-grass prairie, a natural forest cover. Of the active agencies, the climatic factors, precipitation and temperature, are most important; parent material and topography play less significant parts in producing these soils. Precipitation may range from 25 or 30 up to 50 inches or more, variable with the effectiveness of moisture conditions as determined by distribution, evaporation, and textural characteristics of the soil. Temperatures are similarly varied, ranging from below 0° F. to 65° F. or more in January, and from less than 65° F. to more than 80° F. in July. Such climatic conditions favor forest growth, either coniferous or hardwood, and grassland is not characteristic, except locally.

Pedalfers develop under dominantly "degrading" soil-forming processes. Therefore they are gradually deprived of mineral constituents valuable in agriculture. This results from the relatively high temperatures much of the time, the continuously moist subsoil, and the large amount of water in the surface layers, which are therefore subject to extensive leaching, chemical change, and removal of fine material, at their maximum in the top few inches. As a result of these processes, both chemical and mechanical transfer of materials from the surface layers, pedalfers are relatively impoverished soils, for they have lost valuable mineral constituents, especially potassium, phosphorus, and calcium, and gained but

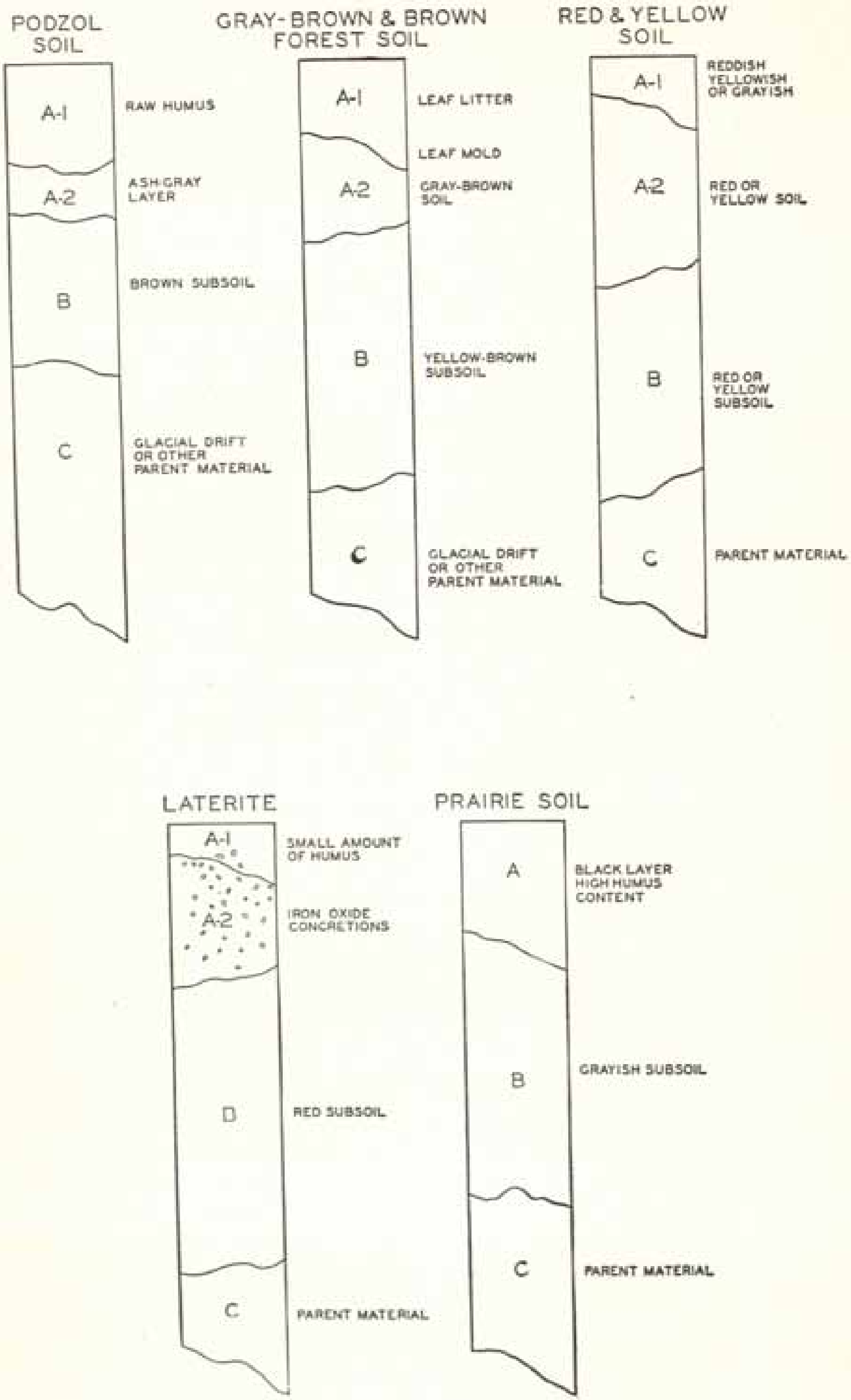


FIG. 457. Profiles of the pedalfers.

little of advantage, since tree roots contribute only a small amount of humus to the soil. Because of these facts, such soils are in general of lesser agricultural desirability than those where the processes described are not so active.

Classes of Pedalfers and Their Characteristics. The pedalfers are divided into four major groups: podzols, gray-brown and brown forest soils, red and yellow and lateritic soils, and prairie soils. The first three of these classes are arranged in east-west belts, succeeding one another from north to south respectively in eastern United States, with the prairie soils on the western margin of all. Farther to the west, pedalfers occur only as scattered outliers. (See Fig. 123.)

Podzols. Podzols are typically soils of the higher latitudes, hence they are extensively developed in New England, across the International Boundary into Canada, and to the west into the Upper Lakes region, with extensions south into the Appalachians and scattered, small occurrences in the plateaus and mountains of the West. All are areas where coniferous forest and plants which flourish on acid soils dominate the native vegetation.

In these soils, the "A" horizon to a depth of a few inches is raw humus (*A1* in Fig. 457), for the generally long, cold winters and moderate summer temperatures retard bacterial action in the surface litter of resinous pine needles. The plane of contact of this strongly acid, spongy layer of raw humus and the underlying mineral matter is sharply defined, largely because of the absence of burrowing animals, particularly earthworms, which elsewhere aid in mixing the organic and mineral material in the surface layers of the soil. Underneath is the thin, ash-gray, highly leached layer (*A2* in Fig. 457) of the "A" horizon, giving the soil its name, podzol, which means "ashes underneath." The typically brown subsoil of the lower or "B" horizon, though relatively high in organic, iron, and alumina content, contains but a small percentage of soluble plant nutrients and it may sometimes develop an impervious layer or hardpan by cementation of the soil particles. Below the subsoil, the parent material of the "C" horizon is frequently glacial drift, for many of the areas of the higher latitudes where podzols occur lie within the limits of glaciation. (See Fig. 460.)

Podzols are not only inferior in their chemical characteristics, but their physical condition is likewise poor, for the surface layers are structureless and therefore difficult to cultivate effectively, in addition to requiring heavy fertilization. This explains in part the failure of agriculture to become established profitably in many of the cut-over areas of the higher latitudes in the United States.

Gray-Brown and Brown Forest Soils. These mildly acid and moderately leached soils normally develop under a deciduous forest cover. The belt they occupy in the United States lies between that of the podzols to the north and that of the red and yellow and lateritic soils to the south, with discontinuous north-south occurrences in the western highlands. These are the only soils of extensive development in both eastern and western United States.

In the gray-brown and brown forest soils, a thin layer of black leaf mold, generally not more than 3 inches thick, underlies the surface cover of leaf litter. (See Fig. 457.) This dark-colored, considerably decomposed accumulation of organic matter rests on a mineral horizon, stained brown by iron oxide. In this horizon, organic material is relatively abundant in the upper part. This imparts a grayish-brown color which gives the name to this soil group. The amount of organic material decreases with depth, the "B" horizon being yellowish brown in color and finer in texture than the overlying layers. (See Fig. 457.) The more southerly the areas of their occurrence, the lighter in tint are all colors, with a tendency for red to appear in the soil profile. The unaltered parent material of the "C" horizon is frequently glacial drift, as with the podzols.

Because of their moderate acidity, the fair reserve of humus, and the presence of limited quantities of critical mineral plant nutrients, newly cleared gray-brown and brown forest soils are generally productive. Unless carefully and well fertilized, however, yields soon decrease under continuous cropping. Nevertheless, the soils of some of the most important agricultural areas of the world, such as those of northeastern United States and northwestern Europe, are gray-brown and brown forest soils.

Red and Yellow and Lateritic Soils. These are the soils of the humid lower latitudes of the United States and other parts of the world, and likewise of the borders of the tropics, where temperatures are moderate to high throughout the year and precipitation is ample in amount.

Like the gray-brown and brown forest soils, they develop under a forest cover, often coniferous but never with an undergrowth of acid-loving vegetation, and the profiles of the two types are similar. However, the dark-colored surface layer of the red and yellow soils is thinner, and the lower surface horizon is predominantly yellow or red rather than brown in color. (See Fig. 457.) Because they occur in areas where temperatures are mild throughout the year, they tend to be badly leached and on the average are poorer soils than are the gray-brown and brown forest soils. This is particularly true where the soil texture is coarse, as it is in much of the Atlantic and Gulf Coastal plains of the United States.

The "A" horizon of mature red and yellow soils consists of a few inches of reddish, yellowish, or grayish soil, darkened slightly by organic mold, in newly cleared land covered by a layer of undecomposed plant litter. In virgin red and yellow soils, this horizon may be grayish in color, but this soon disappears under cultivation, since cropping speedily exhausts the small reserve of organic material and plowing turns up and mixes the underlying reddish material with the thin grayish surface layer. The "B" horizon is low in soluble material, commonly red or yellow in color, and finer in texture. These mildly acid soils develop typically where drainage is good.

The red soils of the margins of the tropics differ from the red and yellow soils of bordering areas of intermediate latitudes but slightly, for they develop under similar conditions. Therefore they are alike in characteristics, except in the degree of their manifestation. In either the tropics or higher latitudes, such soils are soon depleted of both organic and soluble mineral plant nutrients under continuous cultivation without fertilization, but, when used intelligently, as in eastern Asia, they may be kept continuously productive.

Lateritic soils are of but small areal extent in the United States, with their principal development in southern Georgia. There, except for the presence of a thin vein of indurated inclusions of iron oxide, which causes their occurrences to be known locally as "red pebble" or "pimple land," the soil profiles are similar to those of the red and yellow soils. Such lateritic soils are often moderately productive and locally may be regarded as desirable.

In humid tropical areas, where soil-forming processes are much more active than in higher latitudes, laterites rather than lateritic soils are common mature soils, though they are not the most widely distributed nor the best for agricultural use. These deep, permeable, granular soils develop where erosion is slow, temperatures are high, and leaching is continuous and extensive. Therefore they consist of insoluble residues, mainly oxides of iron and alumina, and undissolved silica. They are red in color because of their high iron content.

Laterites are often of extraordinary porosity, the openings between the soil grains sometimes amounting to as much as 70 per cent of the total space they occupy. This is because cementation of the oxides forms aggregates of such size that large openings or pore spaces are left between the individual pellets of the soil. Tropical laterites are poor soils, for the organic litter on the forest floor not only decays rapidly but it is not incorporated with the underlying mineral matter, even where an accumulation of moderate depth occurs.

When cultivated, laterites shortly become unproductive because the small amount of organic material and the mineral plant nutrients are soon used by crops or carried away in solution. Then clearings must be abandoned and new ones made and planted. This is the system of agriculture practiced by the Fang and described in an earlier chapter. Moreover, fertilization is unprofitable, for soil texture and porosity permit too rapid loss of artificially supplied plant nutrients.

Prairie Soils. Lying to the west of the east-west belts of the other pedalfers, and extending south from the Canadian boundary to the prairie lands of Texas, is a belt of soils which developed under a cover of tall grass rather than forest, though precipitation is ample to support tree growth. In this north-south belt, the soils are dark colored in the surface layer, but not brown or yellow nor badly leached. In these respects, the prairie soils differ from other pedalfers but, since they are nonlime-accumulating, they are classified with them.

These soils are confined to interstream areas of regions sufficiently well watered to establish a characteristic downward movement of the soil water into the underground circulation. In the north, such soils are commonly developed on older tills or glacial deposits, especially where loess or wind-blown silt has accumulated either as a veneer or in considerable thickness. In the

south, decomposition of impure limestones has likewise provided conditions which favor growth of tall grasses and development of dark soils of the prairie type. Where tongues of forest invade the grassland, as they do along the stream courses and in hilly country bordering them, prairie soils are displaced by narrow belts of soils of other types.

The profile of a typical prairie soil shows a thick surface layer or "A" horizon of excellent structure, sometimes 2 or more feet in thickness, in which the organic content added by the grass roots is so high that it colors the layer black. Below, the "B" horizon, though lower in organic content, generally contains an abundant supply of mineral plant nutrients.

These prairie soils are in practice deep soils, not easily exhausted, even with abuse under cultivation. Because of their great productivity and the favorable characteristics of the climates in which they develop, the prairie soils, the "corn-belt soils" of Illinois, Iowa, and bordering states, are among the best in the world.

Pedocals. By contrast with the pedalfers, the pedocals of the United States are confined to the West, with their principal occurrences in the Great Plains, east of the Rocky Mountains. Farther west, local developments of pedalfers and extensive rough, stony areas restrict their extent and interfere with their continuity (See Fig. 123.)

Pedocals develop where the maximum precipitation does not exceed 25 and the minimum may be as low as 5 inches, with a moisture supply insufficient to maintain continuous downward movement of soil water. Thus they are soils of drier areas, with their major subdivisions into north-south belts in the United States based on differences in rainfall. Because of their trends, these belts have January temperatures which range from 0° F. to 55° F. and, in July, from 65° F. to 90° F. This introduces minor differences in the soils within each belt.

The pedocals have evolved from a wide variety of parent material, but both that factor and topography, except as the latter may affect maturity, are less important than climate, which makes possible the natural vegetation of grasses and shrubby growths under which pedocals develop. Climate ensures that the soil is continuously moist to only a slight depth. Therefore it is possible for the shallow-rooted herbaceous vegetation to enrich the surface layers with mineral matter brought up from below to an extent which neutralizes the limited leaching occurring during wetter periods. In this movement of soil salts, the calcium carbonate accumulates at various depths below the surface in the "B" horizon (see

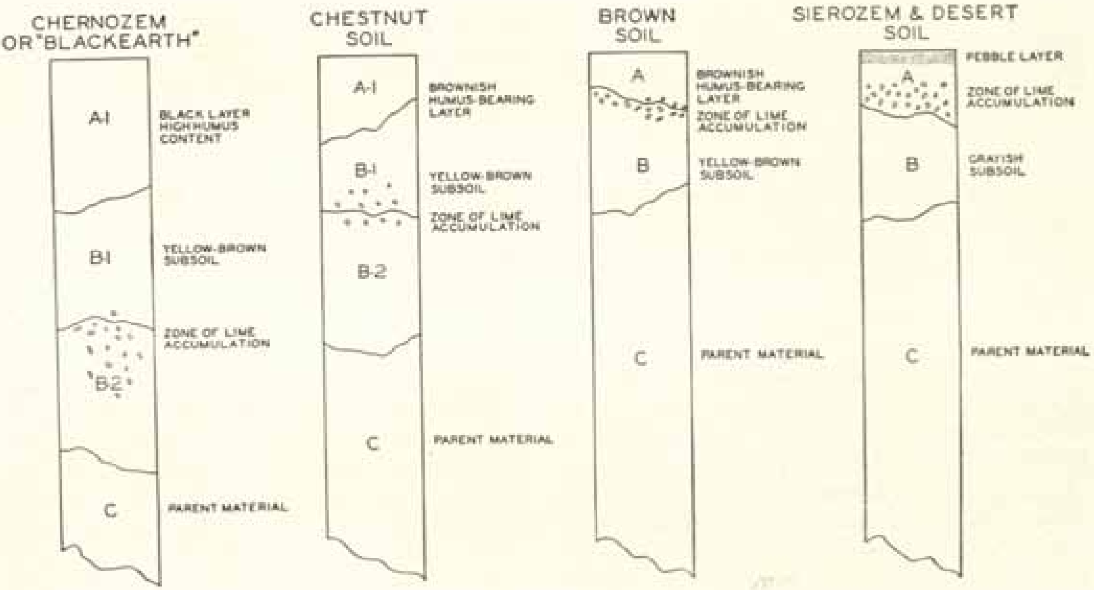


Fig. 458. Profiles of the pedocals.

FIG. 459. Major physical subdivisions of the United States.

Fig. 458), the depth decreasing with increase in aridity. This is why they are known as "pedocals" or "lime-accumulating" soils. By contrast with the pedalfers, which develop under degrading soil conditions, losses in the pedocals are negligible, for leaching is inconsiderable and there is a gain of appreciable amounts of organic substances. The pedocals are likewise favored by physical properties, for texture is normally good and structure is granular and retained under use.

Classes of Pedocals and Their Characteristics. The pedocals are subdivided into four major groups: chernozems, chestnut soils, brown soils, and sierozems and desert soils. These are arranged in north-south belts in the United States, succeeding one another from east to west in the order named, as aridity increases, until desert soils replace them to the west.

Chernozems. These soils develop typically in middle latitudes under a grassland cover, for example, on the eastern margin of the Great Plains in the United States and in southern Russia. Somewhat similar soils are likewise known in the tropics, though these are more like the "black-earths" of Texas than those of Canada and the Dakotas, because of the higher temperatures. Where typically developed, the native vegetation varies from limited growths of tall prairie grass on the wetter, to short steppe grass and brushy growths on the drier margin. Because of the lack of continuity of soil and ground water, except during unusually wet periods, lime is carried upward in solution in such soils and subsequently deposited where the upward movement is offset by leaching. Thus a zone of lime accumulation forms, normally from 3 to 5 feet below the surface, where it is available for vegetation. (See Fig. 458.)

The "A" horizon of chernozems is dark brown to black in color because of the high humus content, granular in structure, and porous. This facilitates effective tillage. The upper part of the "B" horizon is yellow-brown and somewhat leached, but in its lower part is a zone of lime accumulation. (See Fig. 458.) The "C" horizon or parent material, often high in lime, begins at depths of 3 or more feet below the surface.

Chernozems are first-class soils, especially for growing crops like grains, which make heavy drains on soil fertility. Further, the reserve of

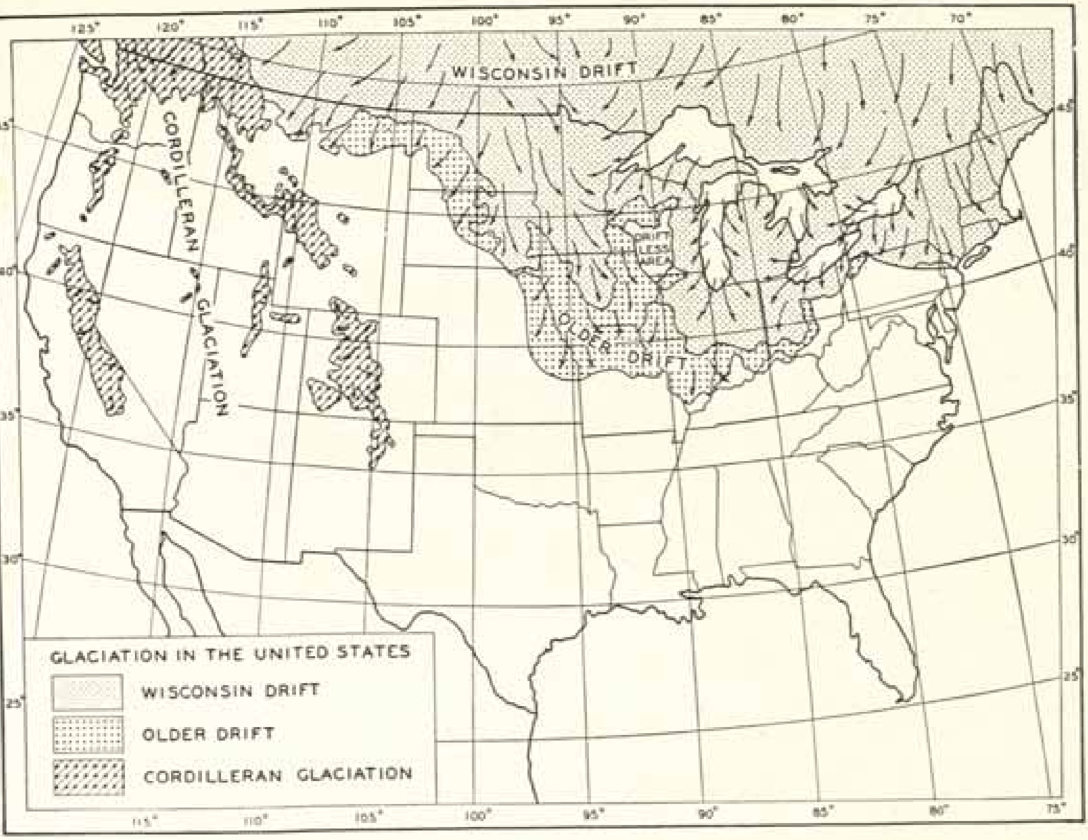


FIG. 460. Glaciation in the United States.

organic and mineral material is so great that they retain their productivity for considerable periods without fertilization. The principal agricultural limitation in areas with such soils is not lack of good soils but the frequent deficiency of precipitation which makes the soils possible.

Chestnut Soils. Chestnut soils are the characteristic soils of areas bordering the drier margins of the belts of chernozems. Like the chernozems or blackearths, they develop under a grassland cover, but though a continuous sod of short grasses is generally present, it is somewhat interrupted where precipitation decreases. Further, the more limited vegetation cover and the relatively dry soil make for a thinner humus-bearing layer at the surface and a brown rather than a black color in the top part of the "A" horizon. Thus the "A" layer contains less humus in its upper part and the zone of lime accumulation is closer to the surface than in the better watered areas with chernozem soils.

The topography of regions where chestnut soils occur is generally favorable for cultivation and soil structure permits effective tillage, but agriculture is rendered hazardous by the small amount of rainfall and its irregular distribution from year to year. Therefore attempts at production have met with frequent disaster in the past and, except in an occasional year, or possibly in a series of more than normally wet years, it is probable that returns from grazing will normally be greater than those from dry farming in areas with such soils.

Brown Soils. These are soils of the belt which adjoins that of chestnut soils on its drier margin, hence the brown soils are even less suitable for agricultural use than are the chestnut soils. In general, they develop under poor steppe conditions, where the sod cover is poor and interrupted by desert growths of brushy vegetation.

The profile of such soils is much like that of other pedocals, except that the humus layer is

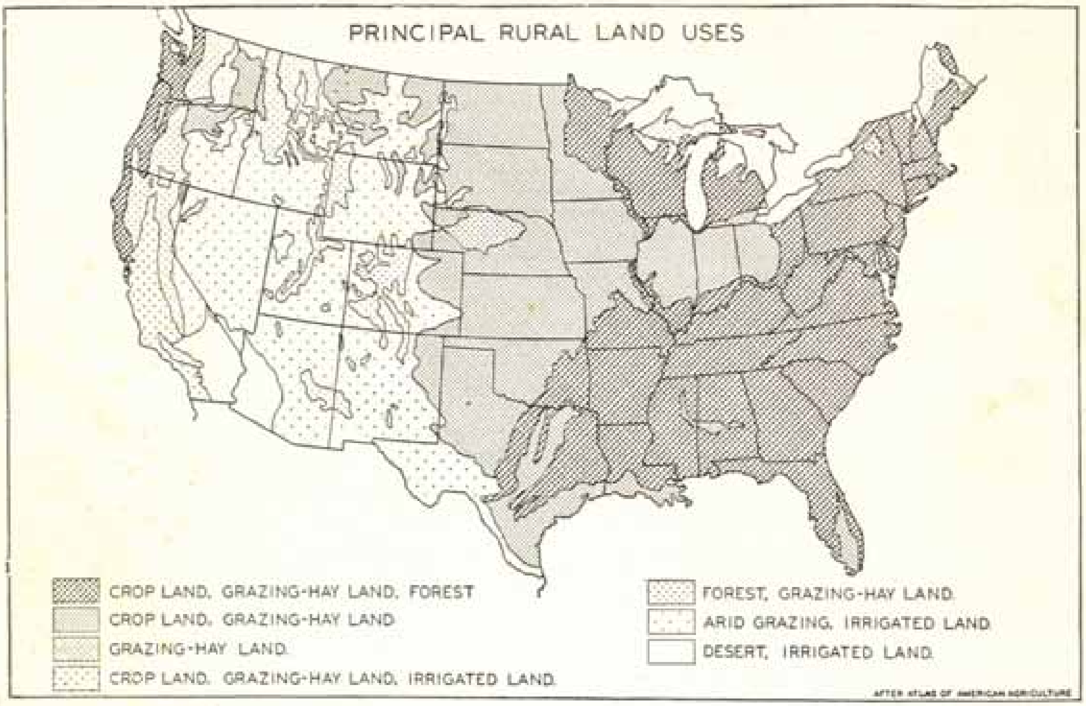


FIG. 461. Principal rural land uses in the United States.

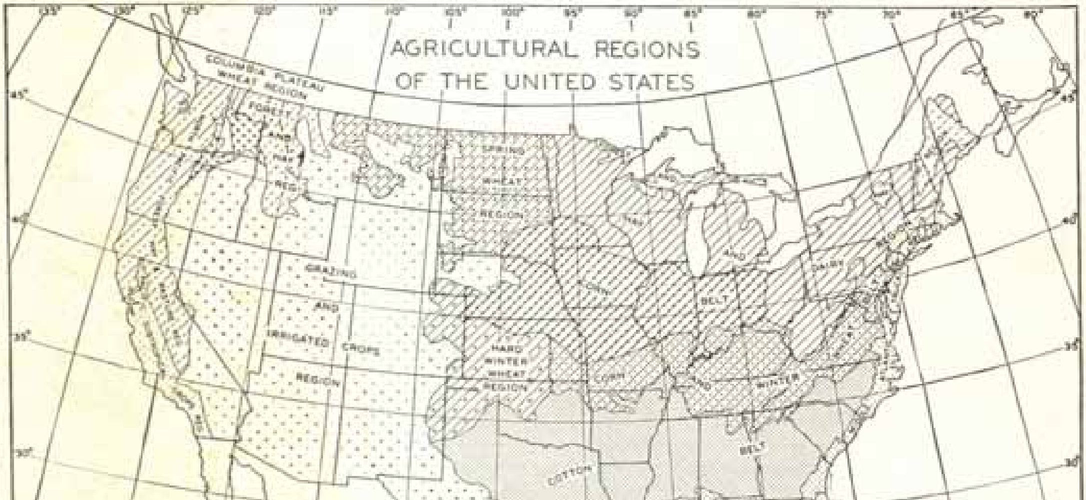


FIG. 462. Agricultural regions of the United States.

thinner and the zone of lime accumulation closer to the surface than in the other types. (See Fig. 458.) Areas with such soils are desirable for grazing but not for agriculture, except under irrigation.

Sierozems and Desert Soils. These soils develop under a sparse cover of widely spaced desert vegetation, largely brushy in type. Further, they lack the dark color of the "A" horizon, characteristic of the pedocals described previously, for the amount of organic material is small. (See Fig. 458.) Again, the concentration of soluble salts occurs very near or even at the surface, where it may form an incrustation in which nothing will grow. In addition to the desert soils with mature profiles, the gray soils, large areas of the true arid lands of the earth's surface are covered with rock wastes in which change has been so slight that the characteristic profiles of mature soils are lacking.

Soils without Profiles. In addition to the mature soils which have been described, there are others in which change has been so slight because of climate, movement of soil-forming material, or some other cause, that characteristic profiles have not developed. These are the soils of the larger portion of the great deserts, those of swamps and marshes, and those of the tundra regions of high latitudes and great elevations.

Soil Groups and Agriculture. The pedalfers are the principal agricultural soils of the United States though, except for the prairie soils, they are inferior to some of the pedocals. This is because precipitation is generally dependable and ample in the areas of their occurrence which, in association with their moderately favorable structure, makes fertilization economic and remunerative agriculture possible, wherever textural characteristics are satisfactory.

By contrast, the pedocals have very desirable soil characteristics, but precipitation is so light, except in the areas with chernozem soils, that agriculture is speculative, unless irrigation water is available. Even then, costs of production are high, for water must be purchased in large amounts. In addition, the supply available is too limited to permit bringing more than a small percentage of the land under ditch. Despite these handicaps, a surprisingly high percentage of the pedocalic area is cropped by use of drought-resistant varieties of the cereals with relatively low water requirements and special methods of cultivation designed to conserve soil moisture.

The prairie soils are the most desirable of the pedalfers for agricultural use, with the gray-brown and brown forest soils, the red and yellow, and the lateritic types following, in the order of their importance. The prairie soils occupy first place because of their favorable structure, slight leaching, and their large reserve of available plant nutrients. The gray-brown and brown forest soils rank second in desirability because of their fairly favorable structure, moderate leaching, and relatively small fertilizer requirement. The other types, the red and yellow and the lateritic soils, are badly leached and much less desirable, and the podzols, the poorest of the pedalfers, suffer from a climatic handicap as well.

Cultivation of the pedocals is largely limited to the chernozem soils and, to a lesser extent, of the chestinut soils. Few of the brown soils or the sierozems and desert soils are under production, except with irrigation. These differences in the extent of use of the various pedocals result from climatic rather than soil factors, for the pedocalic types of the drier areas are but slightly inferior as soils to those where rainfall is heavier.

Not only does the percentage of the different soil types which pass into profitable agricultural use differ as between the pedalfers and pedocals, and within these two groups as well, but the crops grown also vary markedly. In part, this is because of differences in soil characteristics; in part because of climatic variation. For additional discussion of these differences, the student is referred to the selected references at the end of the chapter.

QUESTIONS AND EXERCISES

1. Why has the satisfactory classification of soils been a relatively recent development? How does the present classification differ from those formerly in use? Why is it called an "attributive" system of classification?
2. What are the critical factors which are used in differentiating between soil types in the attributive system of classification? What is the difference between young, mature, and old soils?
3. Into what two major groups are soils divided on the basis of lime accumulation? How do they differ in this respect?

4. Where do the pedalfers occur in the United States? Under what climatic and vegetation conditions do they develop? Under what types of soil-forming processes? How do these processes affect soil desirability? Into what classes are the pedalfers divided?
5. Under what climatic conditions and vegetation cover do podzols develop? Where do they occur in the United States? What are their characteristics? Discuss their agricultural desirability.
6. State the limits of the belt of gray-brown and brown forest soils in the United States. Describe the profile of these soils. Under what conditions do they develop? What is their agricultural desirability?
7. Where do the red and yellow and lateritic soils occur? In what respects do they differ from gray-brown and brown forest soils in profile and productivity? Under what climatic and vegetation conditions do they develop? How do the red soils of the tropics differ from those of intermediate latitudes?
8. Where do lateritic soils develop in the United States? Why are areas with such soils known locally as "pimple land"? Where laterites develop in the tropics, what are their characteristics and agricultural desirability? Why do these characteristics necessitate frequent shifting of clearings under native agricultural use?
9. In what respects do prairie soils differ from the other pedalfers? Where do they occur in the United States? Why are they of such great agricultural desirability?
10. Why are the pedocals confined to western United States? Under what climatic and vegetation conditions do they develop? Why does this ensure a zone of carbonate accumulation in the soil? Why are the pedocals productive soils when water is available? Into what classes are they divided?
11. Where do chernozem soils occur with reference to prairie soils in the United States? Under what type of vegetation cover and what climatic conditions do they develop? Why are they such highly productive soils?
12. Why are the chestnut soils of lesser agricultural desirability than the chernozems? Where are they developed in the United States? How does their profile differ from that of the chernozems?
13. What soils develop on the drier margin of the chestnut soils? Where is the zone of lime accumulation located in such soils? In what respect does climate interfere with the agricultural use of such soils?
14. How do the sierozems and desert soils differ from the other pedocals? Why does the zone of accumulation of mineral salts occur close to or at the surface in such soils?
15. Name the soils without profiles. Why do profiles fail to develop in such soils?
16. Why are the pedalfers the most important agricultural soils in the United States? How do they compare with one another in importance? Why?
17. Why are the pedocals of less agricultural importance than the pedalfers in the United States? Which one of the pedocals is used most extensively for the production of crops? Why?
18. How do crops vary with the soil type? Why?

SELECTED REFERENCES

Kellogg, Charles E., and others, "Soils and Men," *Agricultural Yearbook*, U. S. Department of Agriculture, Washington, 1938, Part IV.

This part of the *Yearbook* contains the following articles: Soil and Society; The Physical Nature of Soil; Water Relations of Soils; General Chemistry of the Soil; Soil Organic Matter and Soil Humus; Fauna and Flora of the Soil; Formation of Soil; Soil Classification; Soil Maps and Their Use; and a description of the Soils of the United States. All sections are written by authorities on soils.

Kellogg, Charles E., *The Soils that Support Us*, The Macmillan Company, New York, 1941, Chaps. VI–X; Appendix I and II.

This is a discussion of soil types and soil classification, accompanied by maps showing the distribution of soil classes and types.

Wolfanger, L., *Major Soil Divisions of the United States*, John Wiley & Sons, Inc., New York, 1930.

This book of 134 small pages is sufficiently simple to be within the understanding of the average reader, yet accurate and authoritative.

Chapter Fifty-Three

SUPPLEMENTARY CLIMATIC MAPS

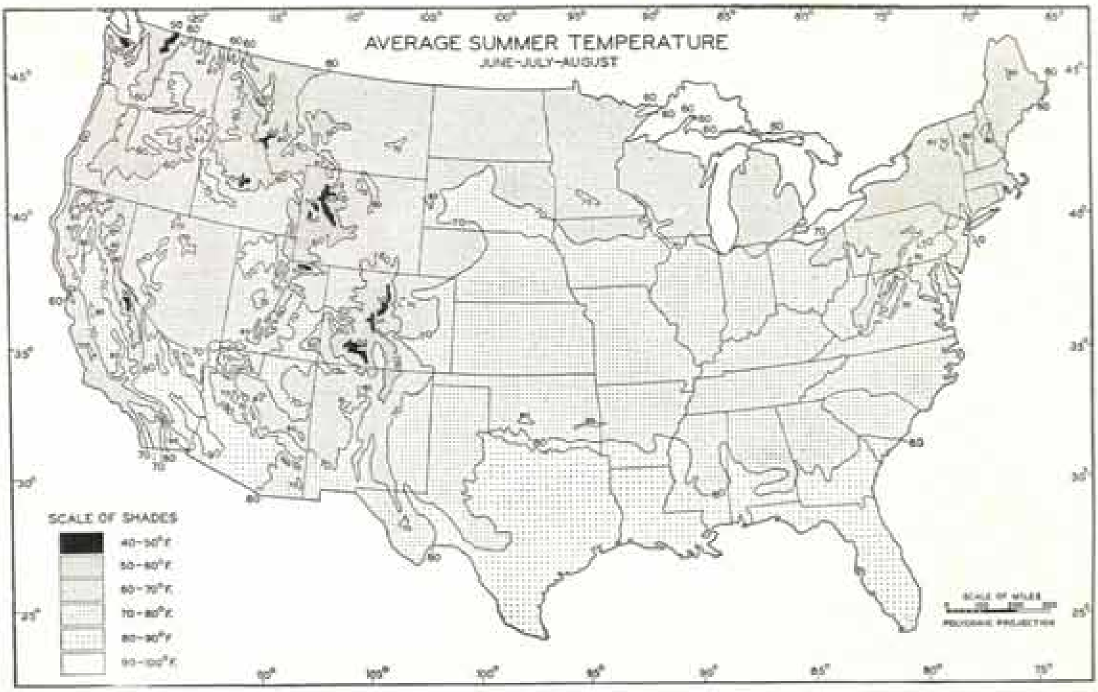


FIG. 463. Average summer temperatures for the United States.

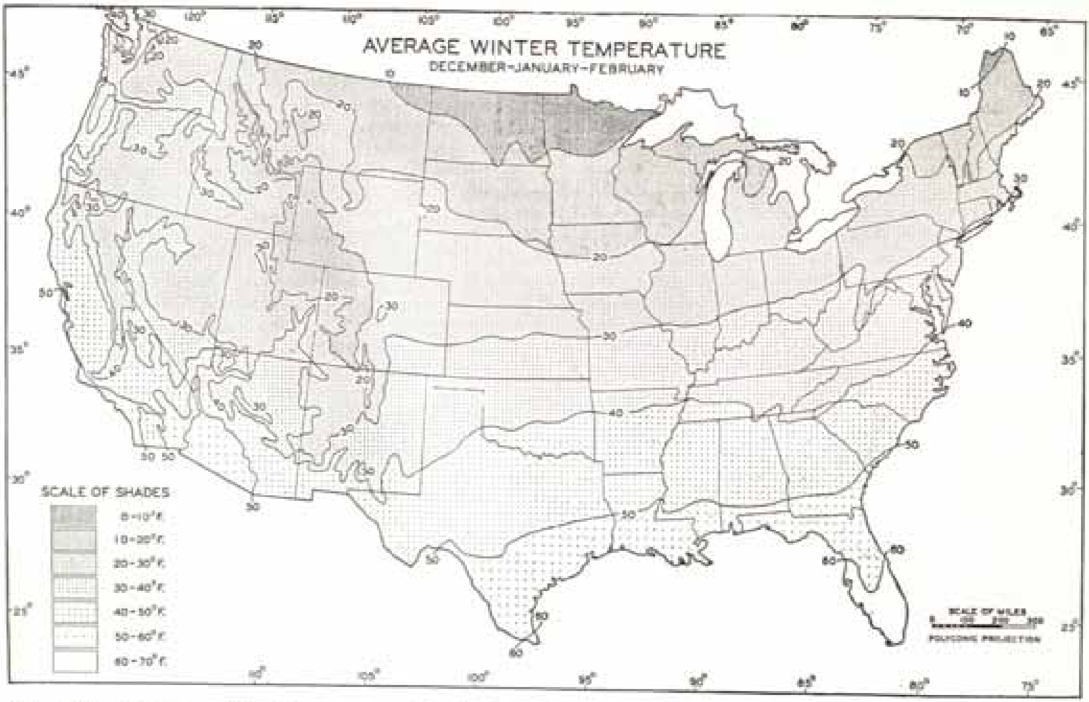


Fig. 464. Average winter temperatures for the United States.

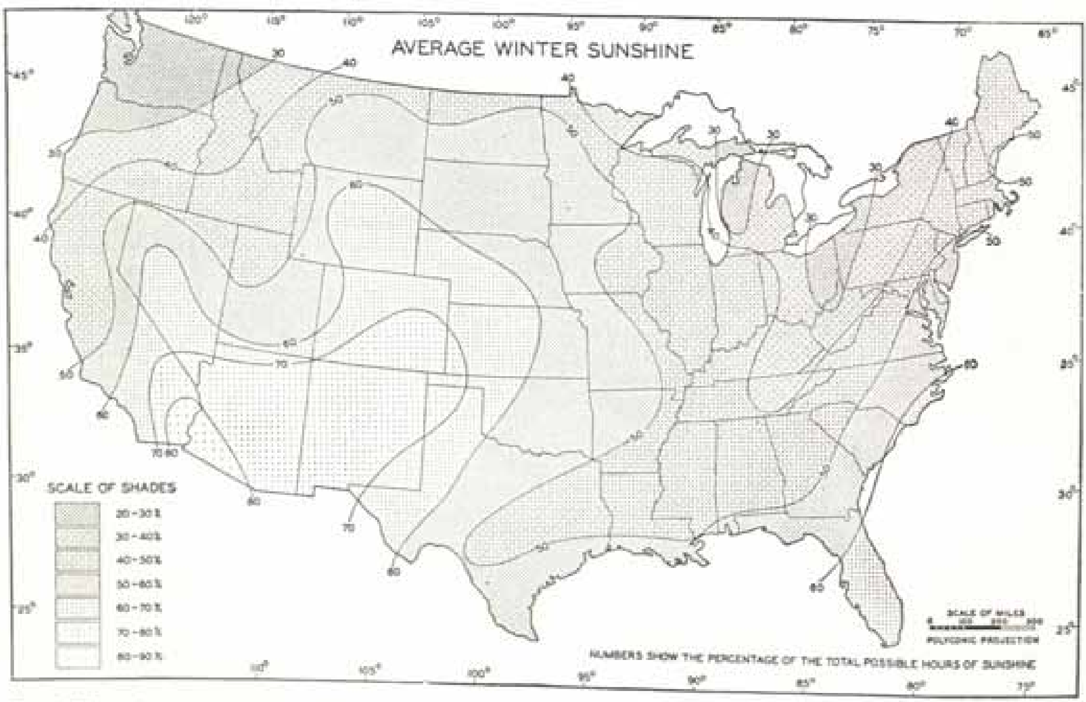


Fig. 465. Average winter sunshine for the United States.

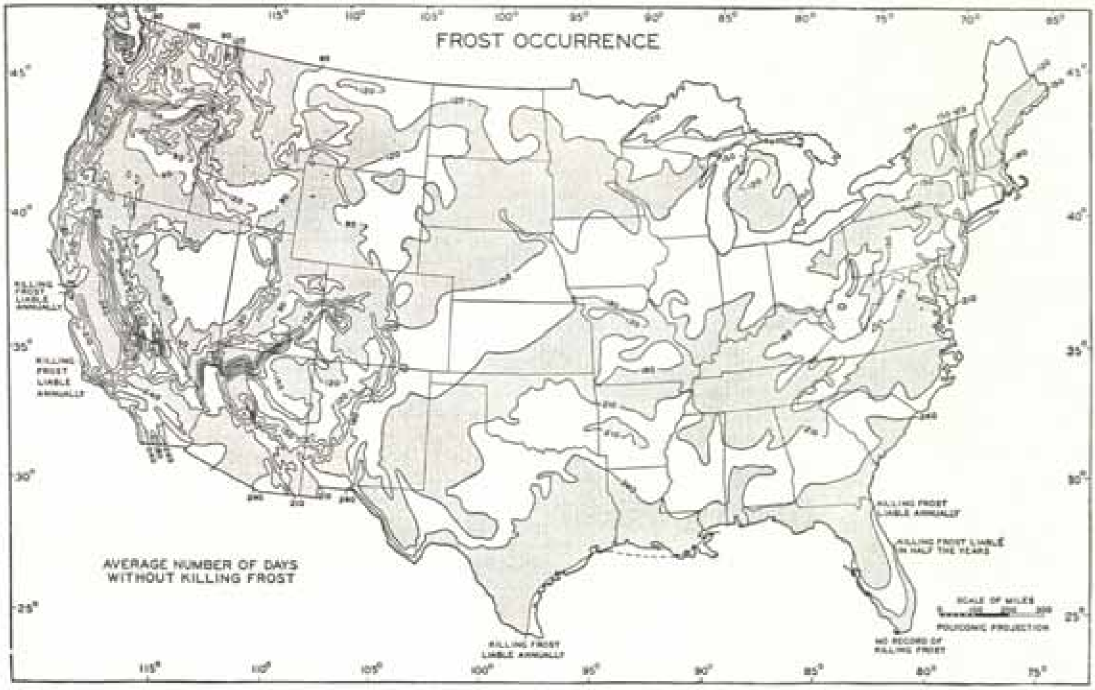


Fig. 466. Average length of the frost-free season for the United States.

Fig. 467. Average dates of the last killing frost in the spring for the United States.

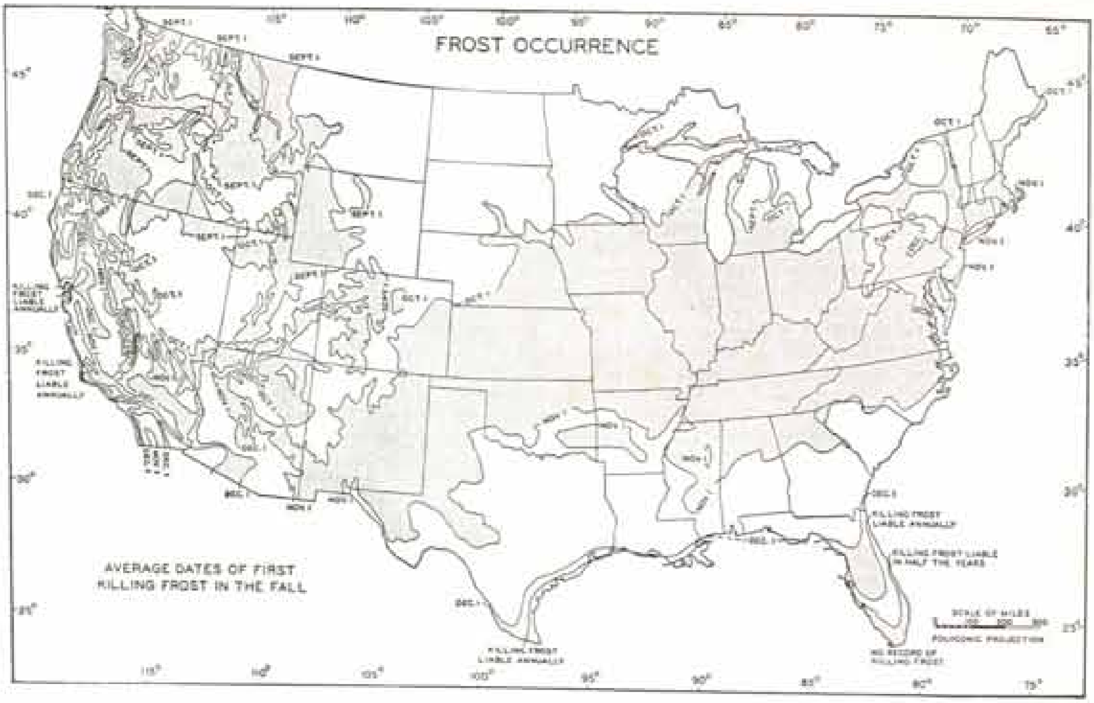


FIG. 468. Average dates of the first killing frost in the fall for the United States.

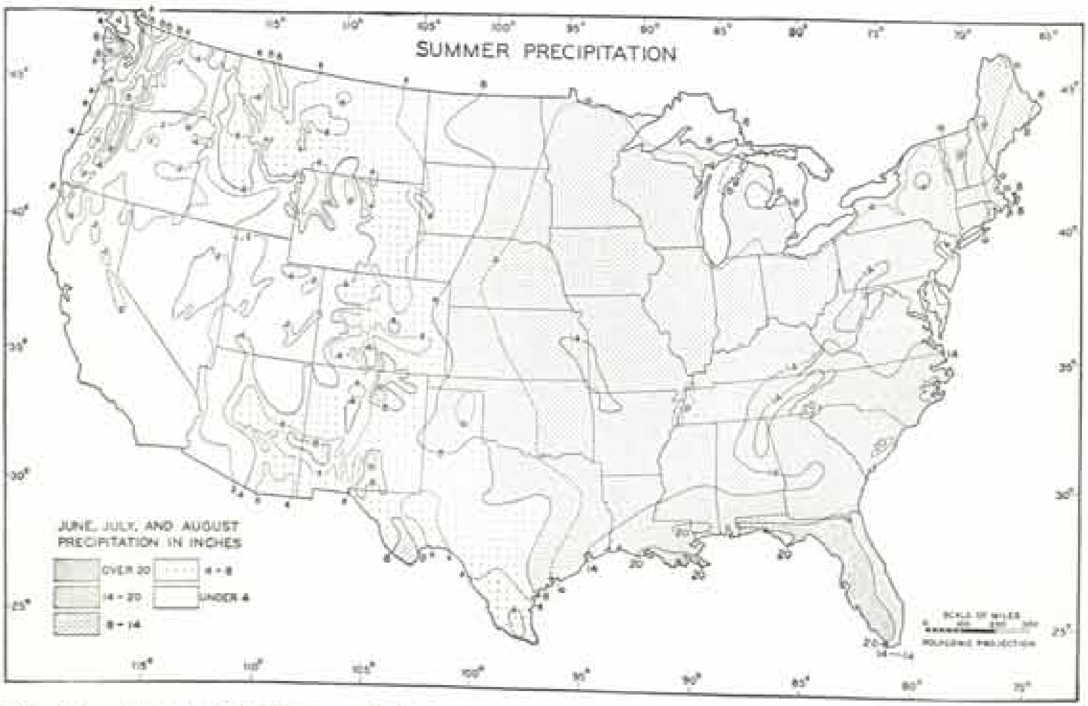


FIG. 469. Amount of summer precipitation in the United States.

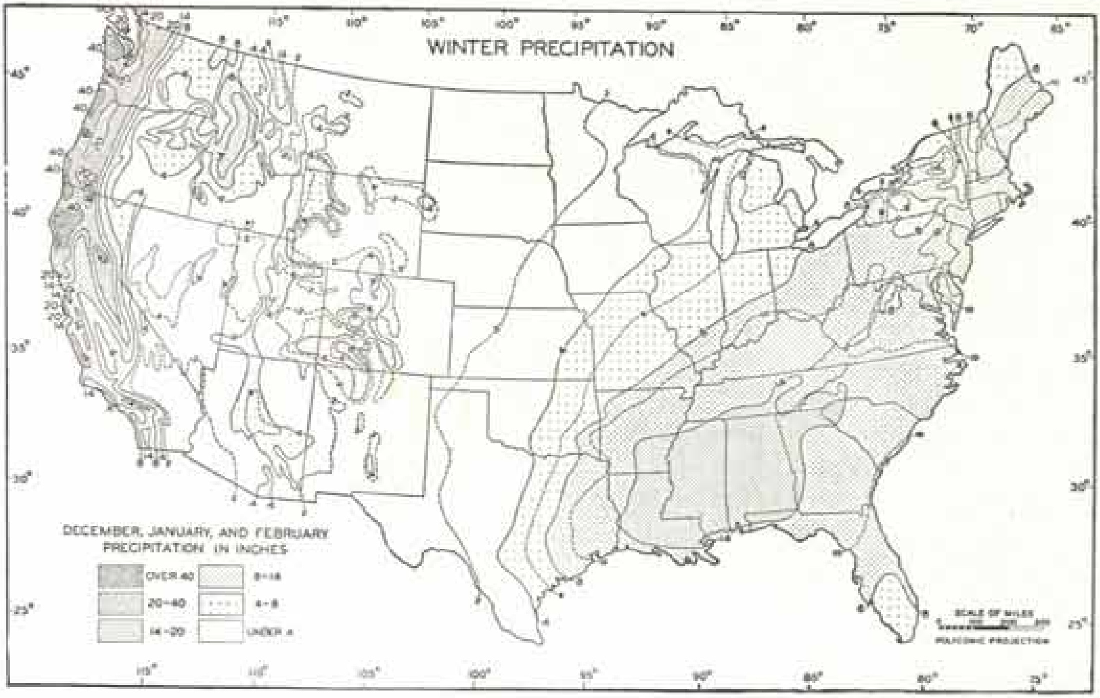


FIG. 470. Amount of winter precipitation in the United States.

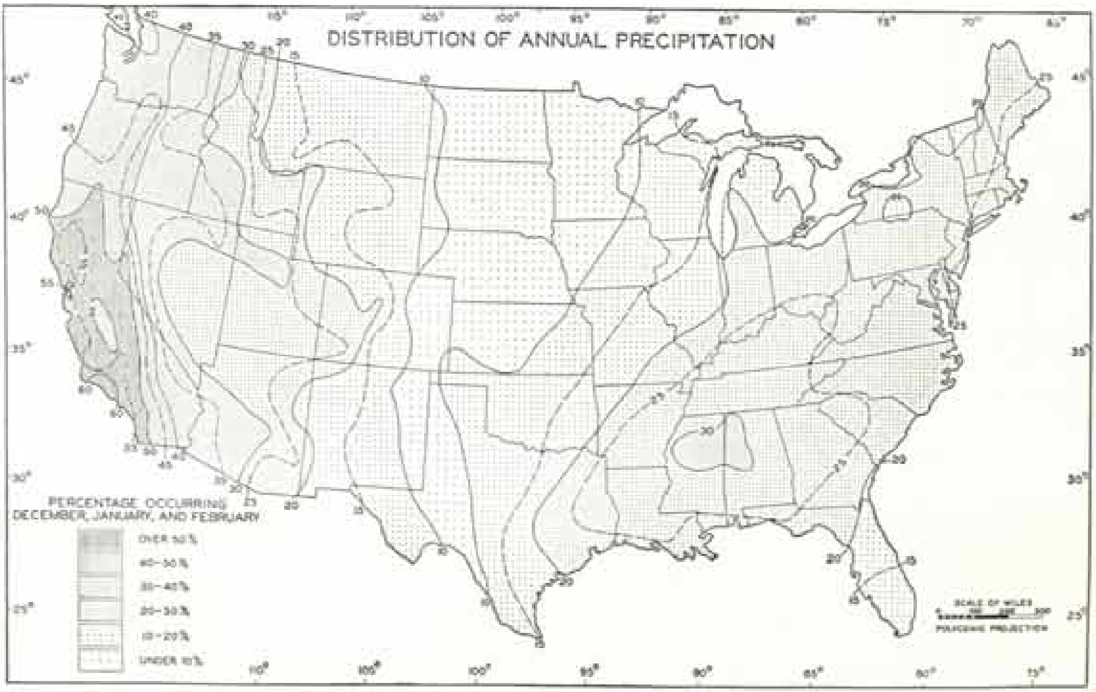


FIG. 471. Percentage of the total precipitation occurring during December, January and February in the United States.

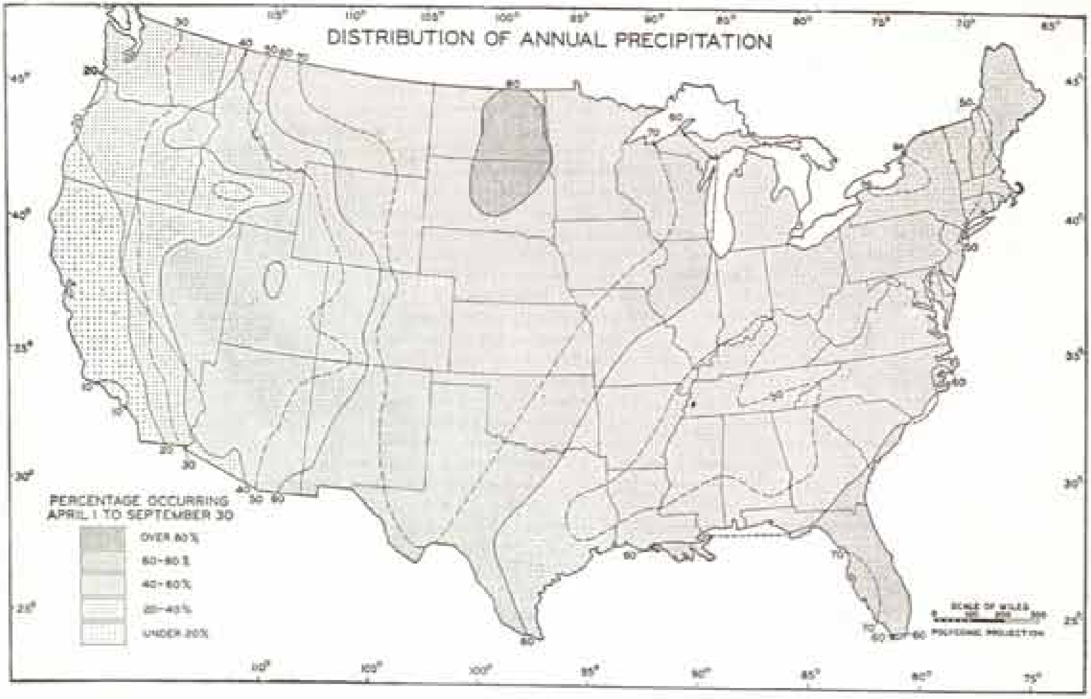


FIG. 472. Percentage of the total precipitation occurring during April to September inclusive in the United States.

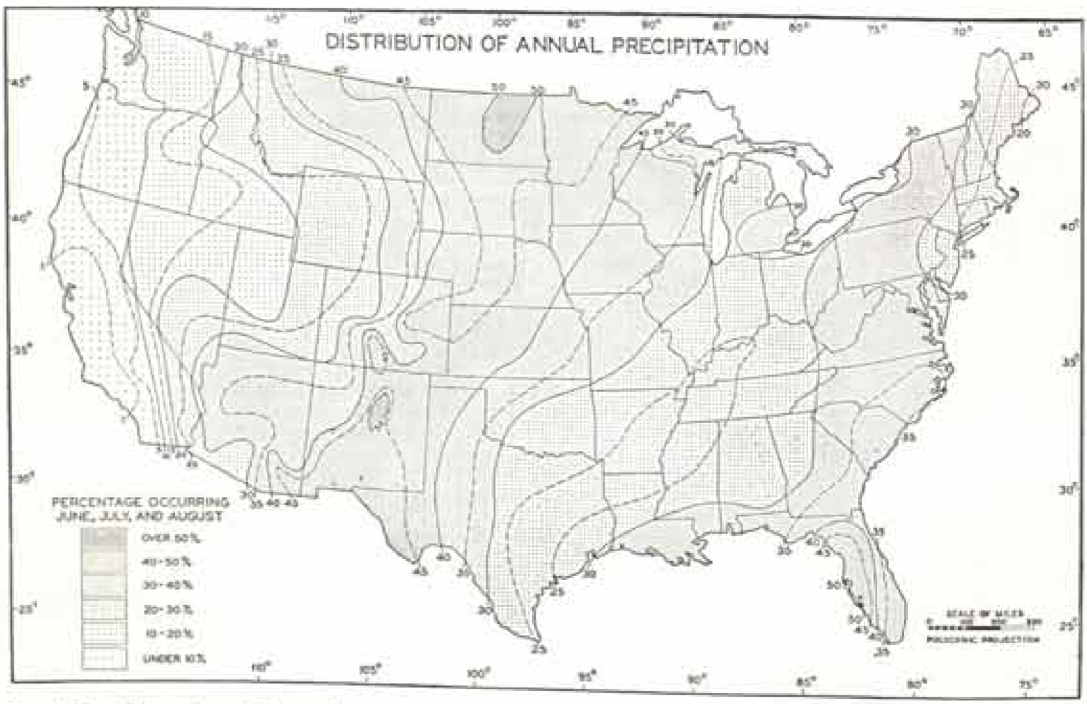


FIG. 473. Percentage of the total precipitation occurring during June, July, and August in the United States.

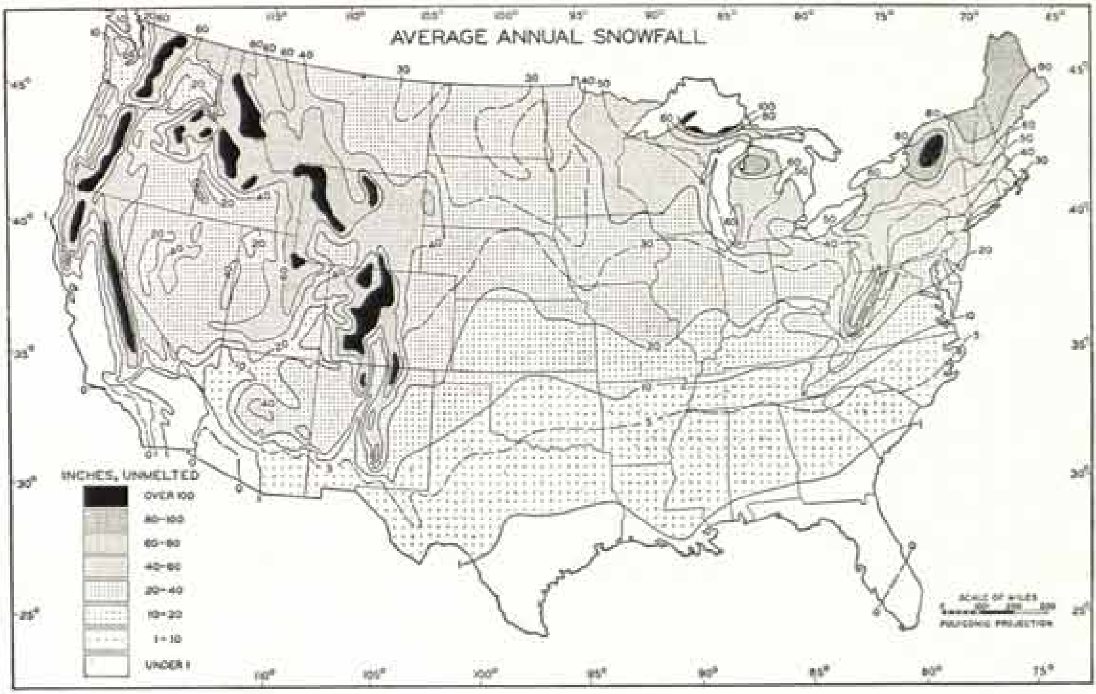


FIG. 474. Average annual snowfall for the United States.

QUESTIONS AND EXERCISES

1. What is the average summer temperature at Detroit, Michigan? At Seattle, Washington? Why are average summer temperatures lower at Seattle than at Detroit?
2. What is the average winter temperature at Portland, Maine? At Portland, Oregon? Why are average winter temperatures higher at Portland, Oregon, than at Portland, Maine?
3. What is the average summer temperature at New York City? At Seattle, Washington? Why is the average temperature at Seattle during the summer lower than at New York City for the same period?
4. What is the average number of days each year without killing frost at Cincinnati, Ohio? At Memphis, Tennessee? How does this affect agriculture and the crops grown?
5. What is the average date of the last killing frost in spring at St. Louis, Missouri? At Toledo, Ohio? How does this difference in the date of the last killing frost in spring affect agriculture?
6. What is the average date of the first killing frost in the fall at Boston, Massachusetts? At Minneapolis, Minnesota? Why does the first killing frost in fall occur earlier at Minneapolis than it does at Boston?
7. How many inches of precipitation fall at Chicago on the average during the 3 summer months? Is this more or less than the average winter precipitation for Chicago? Is this an advantage or a disadvantage? Why?
8. How many inches of precipitation fall at Los Angeles, California on the average during the 3 winter months? Is this more or less than the average for the 3 summer months? Is this an advantage or a disadvantage? Why?
9. What percentage of the total annual precipitation of eastern North Dakota falls during the 3 winter months? During the 3 summer months? Is this distribution of precipitation advantageous or does it constitute a handicap? Why?
10. What percentage of the total annual precipitation of the Los Angeles area falls during the months April to September inclusive? Why is this percentage so small?
11. What percentage of the annual precipitation of the San Francisco area falls during the 3 summer months? Why is this percentage so small?
12. Compare the average annual snowfall of the area near Buffalo, New York, with that of eastern Montana. Explain why the amounts are so different.

Chapter Fifty-Four

MISCELLANEOUS TABLES

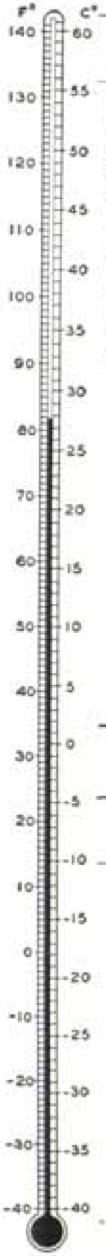


TABLE IA—FAHRENHEIT SCALE TO CENTIGRADE

°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.
110	43.3	85	29.4	60	15.6	35	1.7	10	12.2	15	26.1
109	42.8	84	28.9	59	15.0	34	1.1	9	12.8	16	26.7
108	42.2	83	28.3	58	14.4	33	+0.6	8	13.3	17	27.2
107	41.7	82	27.8	57	13.9	32	0.0	7	13.9	18	27.8
106	41.1	81	27.2	56	13.3	31	−0.6	6	14.4	19	28.3
105	40.6	80	26.7	55	12.8	30	1.1	5	15.0	20	28.9
104	40.0	79	26.1	54	12.2	29	1.7	4	15.6	21	29.4
103	39.4	78	25.6	53	11.7	28	2.2	3	16.1	22	30.0
102	38.9	77	25.0	52	11.1	27	2.8	2	16.7	23	30.6
101	38.3	76	24.4	51	10.6	26	3.3	+1	17.2	24	31.1
100	37.8	75	23.8	50	10.0	25	3.9	0	17.8	25	31.7
99	37.2	74	23.3	49	9.4	24	4.4	−1	18.3	26	32.2
98	36.7	73	22.8	48	8.9	23	5.0	2	18.9	27	32.8
97	36.1	72	22.2	47	8.3	22	5.6	3	19.4	28	33.3
96	35.6	71	21.7	46	7.8	21	6.1	4	20.0	29	33.9
95	35.0	70	21.1	45	7.2	20	6.7	5	20.6	30	34.4
94	34.4	69	20.6	44	6.7	19	7.2	6	21.1	31	35.0
93	33.9	68	20.0	43	6.1	18	7.8	7	21.7	32	35.6
92	33.3	67	19.4	42	5.6	17	8.3	8	22.2	33	36.1
91	32.8	66	18.9	41	5.0	16	8.9	9	22.8	34	36.7
90	32.2	65	18.3	40	4.4	15	9.4	10	23.3	35	37.2
89	31.7	64	17.8	39	3.9	14	10.0	11	23.9	36	37.8
88	31.1	63	17.2	38	3.3	13	10.6	12	24.4	37	38.3
87	30.6	62	16.7	37	2.8	12	11.1	13	25.0	38	38.9
86	30.0	61	16.1	36	2.2	11	11.7	14	25.6	39	39 4

TABLE 1B—CENTIGRADE SCALE TO FAHRENHEIT

°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.
40	104.0	25	77.0	10	50.0	5	23.0	20	4.0
39	102.2	24	75.2	9	48.2	6	21.2	21	5.8
38	100.4	23	73.4	8	46.4	7	19.4	22	7.6
37	98.6	22	71.6	7	44.6	8	17.6	23	9.4
36	96.8	21	69.8	6	42.8	9	15.8	24	11.2
35	95.0	20	68.0	5	41.0	10	14.0	25	13.0
34	93.2	19	66.2	4	39.2	11	12.2	26	14.8
33	91.4	18	64.4	3	37.4	12	10.4	27	16.6
32	89.6	17	62.6	2	35.6	13	8.6	28	18.4
31	87.8	16	60.8	+1	33.8	14	6.8	29	20.2
30	86.0	15	59.0	0	32.0	15	5.0	30	22.0
29	84.2	14	57.2	−1	30.2	16	3.2	31	23.8
28	82.4	13	55.4	2	28.4	17	1.4	32	25.6
27	80.6	12	53.6	3	26.6	18	−0.4	33	27.4
26	78.8	11	51.8	4	24.8	19	2.2	34	29.2

FIG. 475. Thermometer graduated in both Fahrenheit and Centigrade scales.

TABLE II. RELATIVE HUMIDITY, PER CENT—FAHRENHEIT DEGREES PRESSURE: 30.0 INCHES[1]

Air Temperature	*Depression of Wet-bulb Thermometer*																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
20	10																	
15	31																	
10	46																	
−5	58	16																
0	67	33	1															
+5	73	46	20															
10	78	56	34	13														
15	82	64	46	29														
20	85	70	55	40	26	12												
25	87	74	62	49	37	25	13	1										
30	89	78	67	56	46	36	26	16	6									
35	91	81	72	63	54	45	36	27	19	10	2							
40	92	83	75	68	60	52	45	37	29	22	15	7	0					
45	93	86	78	71	64	57	51	44	38	31	25	18	12	6				
50	93	87	80	74	67	61	55	49	43	38	32	27	21	16	10	5	0	
55	94	88	82	76	70	65	59	54	49	43	38	33	28	23	19	14	9	5
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13
65	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35
86	96	92	88	84	81	77	73	70	66	62	60	57	53	50	47	44	42	39
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41
96	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51	49	46	43
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46

TABLE II (*Continued*)

Air Temperature	*Depression of Wet-bulb Thermometer*																							
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
55	0																							
60	9	5	1																					
65	16	12	9	5	2																			
70	22	19	15	12	9	6	3																	
75	27	24	21	18	15	12	9	7	4															
80	32	29	26	23	20	18	15	12	10	7	5	3	0											
86	36	33	31	28	26	23	21	18	16	14	11	9	7	5	3	1								
90	39	36	34	31	29	26	24	22	19	17	15	13	11	9	7	5	3	1						
94	41	38	36	33	31	29	27	24	22	20	18	16	14	12	10	9	7	5	3	1				
100	44	41	39	37	35	33	30	28	26	24	22	21	19	17	15	13	12	10	8	7	5	4	3	1

[1] After Psychrometric Tables, U. S. Weather Bureau Bulletin 235, 1915.

TABLE III. CONVERSION OF MILLIBARS TO INCHES[1]

Mb.	*Inches*	*Mb.*	*Inches*	*Mb.*	*Inches*	*Mb.*	*Inches*	*Mb.*	*Inches*	*Mb.*	*Inches*
941	27.79	961	28.38	981	28.97	1001	29.56	1021	30.15	1041	30.74
942	27.82	962	28.41	982	29.00	1002	29.59	1022	30.18	1042	30.77
943	27.85	963	28.44	983	29.03	1003	29.62	1023	30.21	1043	30.80
944	27.88	964	28.47	984	29.06	1004	29.65	1024	30.24	1044	30.83
945	27.91	965	28.50	985	29.09	1005	29.68	1025	30.27	1045	30.86
946	27.94	966	28.53	986	29.12	1006	29.71	1026	30.30	1046	30.89
947	27.96	967	28.56	987	29.15	1007	29.74	1027	30.33	1047	30.92
948	27.99	968	28.58	988	29.18	1008	29.77	1028	30.36	1048	30.95
949	28.02	969	28.61	989	29.21	1009	29.80	1029	30.39	1049	30.98
950	28.05	970	28.64	990	29.23	1010	29.83	1030	30.42	1050	31.01
951	28.08	971	28.67	991	29.26	1011	29.85	1031	30.45	1051	31.04
952	28.11	972	28.70	992	29.29	1012	29.88	1032	30.47	1052	31.07
953	28.14	973	28.73	993	29.32	1013	29.91	1033	30.50	1053	31.10
954	28.17	974	28.76	994	29.35	1014	29.94	1034	30.53	1054	31.12
955	28.20	975	28.79	995	29.38	1015	29.97	1035	30.56	1055	31.15
956	28.23	976	28.82	996	29.41	1016	30.00	1036	30.59	1056	31.18
957	28.26	977	28.85	997	29.44	1017	30.03	1037	30.62	1057	31.21
958	28.29	978	28.88	998	29.47	1018	30.06	1038	30.65	1058	31.24
959	28.32	979	28.91	999	29.50	1019	30.09	1039	30.68	1059	31.27
960	28.35	980	28.94	1000	29.53	1020	30.12	1040	30.71	1060	31.30

[1] After U. S. Weather Bureau, Form No. 4090, Mis.

TABLE IV. CLIMATIC DATA FOR SELECTED STATIONS

(T., temperature in degrees Fahrenheit; Rf., rainfall in inches.)

NORTH AMERICA

		Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Bismarck,	T.	7.8	10.3	24.2	42.1	54.5	63.7	69.8	67.3	58.1	44.9	28.5	14.7	40.5
U. S. A.	Rf.	0.5	0.5	1.1	1.8	2.4	3.4	2.2	2.0	1.2	1.0	0.7	0.6	17.4
Boise,	T.	29.8	34.8	42.7	50.4	57.1	65.3	72.9	71.8	61.9	51.1	41.0	32.1	50.9
U. S. A.	Rf.	1.7	1.4	1.3	1.2	1.4	1.0	0.2	0.2	0.6	1.2	1.3	1.6	13.1
Boston,	T.	27.9	28.8	35.6	46.4	57.1	66.5	71.7	69.9	63.2	53.6	42.0	32.5	49.6
U. S. A.	Rf.	3.6	3.4	3.6	3.3	3.2	2.9	3.5	3.6	3.1	3.1	3.3	3.4	40.0
Charleston,	T.	49.9	52.4	57.4	64.5	72.7	78.9	81.4	81.0	76.6	67.8	58.1	51.7	66.0
U. S. A.	Rf.	3.1	3.1	3.3	2.4	3.4	5.3	6.2	6.7	5.2	3.9	2.7	3.3	48.6
Chicago,	T.	25.6	27.0	36.6	47.4	58.4	68.1	74.0	72.9	66.3	54.8	41.5	30.3	50.2
U. S. A.	Rf.	2.0	2.1	2.6	2.8	3.6	3.3	3.4	3.0	3.1	2.6	2.4	2.1	33.0
Calgary,	T.	12.7	13.8	22.8	39.7	48.8	52.6	60.7	59.1	50.2	42.1	25.5	20.9	37.4
Canada	Rf.	0.4	0.6	0.8	0.7	2.5	3.1	2.6	2.6	1.2	0.5	0.7	0.5	16.2
Colon,	T.	79.5	79.2	79.7	79.9	79.9	79.9	80.1	79.3	79.5	79.0	79.0	79.5	79.5
Canal Zone	Rf.	3.9	1.7	1.7	4.2	12.6	13.5	16.2	14.9	12.5	14.8	21.5	11.9	129.4
Dawson,	T.	−23.1	−11.3	3.8	29.1	46.4	56.7	59.3	54.3	42.4	25.1	0.7	−13.1	22.5
Canada	Rf.	0.8	0.8	0.5	0.7	0.9	1.3	1.6	1.6	1.7	1.3	1.3	1.1	13.6
Detroit,	T.	24.4	25.3	33.4	46.2	58.0	67.4	72.1	70.3	63.5	52.5	39.3	29.3	48.5
U. S. A.	Rf.	2.0	2.2	2.4	2.5	3.2	3.6	3.3	2.8	2.9	2.4	2.4	2.3	32.0
Havana,	T.	70.3	72.0	73.4	76.3	79.2	81.3	81.9	81.5	80.4	77.9	74.7	71.6	76.6
Cuba	Rf.	2.7	2.3	1.8	2.8	4.5	7.2	5.0	6.0	6.7	7.4	3.1	2.2	51.7
Ivigtut,	T.	18.5	18.7	23.5	30.9	40.1	46.6	49.8	47.3	41.0	33.8	26.4	20.7	33.1
Greenland	Rf.	3.3	2.7	3.4	2.4	3.6	3.0	3.3	3.8	6.0	5.9	4.4	3.1	44.9

TABLE IV. CLIMATIC DATA FOR SELECTED STATIONS (*Continued*)

NORTH AMERICA (*Continued*)

		Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Los Angeles,	T.	54.6	55.5	57.5	59.4	62.2	66.4	70.2	71.1	69.0	65.3	60.9	56.6	62.4
U. S. A.	Rf.	3.1	3.1	2.8	1.0	0.4	0.1	0.0	0.0	0.2	0.7	1.2	2.6	15.2
Mexico City,	T.	54.0	56.8	60.4	64.2	64.9	63.9	62.4	62.1	61.2	58.6	56.5	53.4	59.9
Mexico	Rf.	0.2	0.2	0.6	0.6	1.9	3.9	4.1	4.7	4.1	1.8	0.5	0.2	23.1
Monterrey,	T.	57.9	61.7	67.8	73.0	79.0	81.9	82.2	82.6	78.1	71.4	63.5	57.4	71.4
Mexico	Rf.	0.5	0.5	0.7	1.1	1.2	2.3	2.1	2.0	4.4	2.4	1.3	1.0	19.5
Montreal,	T.	13.0	14.7	25.4	41.1	55.1	64.7	69.3	67.0	58.7	46.7	32.7	19.1	42.3
Canada	Rf.	3.7	3.2	3.7	2.4	3.1	3.4	3.7	3.3	3.5	3.3	3.4	3.7	40.4
New Orleans,	T.	54.5	57.3	62.8	68.8	75.4	80.6	82.4	82.2	79.2	71.0	61.6	55.6	69.2
U. S. A.	Rf.	4.3	4.2	4.7	5.2	4.6	5.9	6.4	5.8	5.0	3.3	3.1	4.8	57.3
New York,	T.	30.6	30.5	38.0	48.5	59.4	68.5	73.5	72.1	66.4	55.8	44.1	34.3	51.8
U. S. A.	Rf.	3.2	3.3	3.4	3.3	3.5	3.5	4.1	4.3	3.4	3.4	3.4	3.3	42.1
Phoenix,	T.	51.2	55.1	60.7	67.0	75.0	84.5	89.8	88.5	82.7	70.6	59.7	52.0	69.7
U. S. A.	Rf.	0.8	0.8	0.7	0.4	0.1	0.1	1.1	1.0	0.7	0.5	0.7	1.0	7.8
Pt. Barrow,	T.	−19.9	−13.0	−13.1	−1.7	21.7	35.3	40.9	38.5	32.1	16.3	0.3	−15.4	10.2
Alaska	Rf.	0.1	0.4	0.2	0.3	0.3	0.3	0.9	0.9	0.5	0.7	0.3	0.4	5.3
Portland,	T.	38.9	41.5	46.3	51.2	56.6	61.4	66.6	66.4	60.9	53.6	45.9	41.0	52.5
Oregon	Rf.	6.5	5.5	4.8	3.0	2.3	1.6	0.6	0.6	1.9	3.2	6.5	6.9	43.5
Salt Lake,	T.	29.0	33.4	41.3	49.8	57.4	66.9	75.5	74.5	64.4	52.3	40.6	32.1	51.4
U. S. A.	Rf.	1.3	1.5	2.0	2.1	2.2	0.8	0.5	0.8	0.9	1.4	1.4	1.4	16.3
Sagdlit,	T.	22.5	22.3	25.7	31.3	35.8	39.0	39.9	40.1	38.8	34.3	30.9	26.2	32.2
Greenland	Rf.	....	....	....	....	....	....	....	....	....	....	....	....	....
St. Louis,	T.	31.6	33.7	44.2	55.8	66.2	75.0	79.2	77.3	70.1	58.3	45.4	35.6	56.0
U. S. A.	Rf.	2.3	2.6	3.5	3.8	4.5	4.6	3.6	3.5	3.2	2.8	2.9	2.5	39.8
St. Paul,	T.	12.1	15.2	29.0	45.6	58.6	67.4	72.3	69.4	60.6	48.1	32.1	19.8	44.2
U. S. A.	Rf.	0.9	0.9	1.5	2.3	3.5	4.3	3.5	3.3	3.1	2.3	1.3	1.0	27.9
San Francisco,	T.	49.4	51.4	52.8	54.3	55.5	57.2	57.3	57.8	59.9	58.9	55.5	50.6	55.0
U. S. A.	Rf.	4.8	3.6	3.1	1.6	0.7	0.1	0.0	0.0	0.3	0.9	2.4	4.5	22.0
Sitka,	T.	31.7	34.1	36.5	41.3	46.6	51.3	54.8	55.5	51.7	45.8	38.2	35.4	43.6
Alaska	Rf.	7.6	6.5	5.6	5.5	4.1	3.4	4.2	7.1	10.1	12.2	9.5	9.0	84.8
Washington,	T.	32.9	34.5	42.2	53.1	64.2	72.7	76.8	74.5	68.1	56.6	45.0	36.1	54.7
D. C.	Rf.	3.1	3.1	3.5	3.3	3.7	3.7	4.3	4.1	3.3	3.1	2.6	3.0	40.8
Winnipeg,	T.	−2.6	−1.0	14.7	38.6	51.1	62.1	65.9	63.1	53.9	41.5	24.5	7.4	34.9
Canada	Rf.	0.9	0.8	1.3	1.6	2.2	3.3	3.2	2.2	1.9	1.4	1.0	0.9	20.7

SOUTH AMERICA

Bogota,	T.	56.7	57.9	58.6	58.6	58.5	58.1	57.2	57.0	57.0	57.9	58.3	58.1	58.1
Colombia	Rf.	3.7	3.5	4.5	9.6	6.5	3.2	2.6	3.3	2.9	8.4	9.6	5.6	63.4
Buenos Aires,	T.	73.6	72.5	68.7	61.3	55.0	49.6	48.9	51.1	55.0	59.9	65.8	70.9	61.3
Argentina	Rf.	3.1	2.7	4.4	3.5	2.9	2.5	2.2	2.5	3.0	3.5	3.1	3.9	37.0
Caracas,	T.	68.5	68.9	69.3	72.5	73.9	73.0	72.0	72.7	72.5	71.4	71.2	68.9	71.2
Venezuela	Rf.	0.9	0.3	0.6	1.2	2.8	4.0	4.8	3.8	4.2	4.4	3.3	1.6	31.9
Córdoba,	T.	73.8	72.5	68.5	62.1	55.8	49.6	50.4	51.6	58.6	63.3	68.4	72.3	62.2
Argentina	Rf.	4.2	4.2	3.5	1.8	1.0	0.3	0.3	0.5	0.9	2.4	4.0	4.6	27.7
Cuiabá,	T.	81.0	80.8	80.7	80.2	77.5	75.4	75.9	78.3	82.0	81.7	82.0	81.3	79.8
Brazil	Rf.	9.8	8.3	8.3	4.0	2.0	0.3	0.2	1.1	2.2	4.5	5.9	8.1	54.7
Iquique,	T.	69.4	69.4	67.6	64.8	62.6	61.2	60.4	60.3	61.2	63.0	65.3	67.5	64.4
Chile	Rf.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Lima,	T.	72.7	74.3	73.6	70.2	66.0	62.6	61.2	61.0	61.3	63.0	65.7	70.0	66.8
Peru	Rf.	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.4	0.2	0.1	0.0	1.7

SOUTH AMERICA (*Continued*)

		Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Manáos,	T.	79.9	80.1	79.7	79.9	80.1	80.1	80.6	81.7	82.8	82.8	82.2	80.6	80.9
Brazil	Rf.	9.2	9.0	9.6	8.5	7.0	3.6	2.2	1.4	2.0	4.1	5.5	7.7	69.8
Port-of-Spain,	T.	75.2	75.4	76.3	77.8	79.1	78.1	77.9	77.8	78.3	78.2	77.5	76.3	77.3
Trinidad	Rf.	2.7	1.5	1.8	1.8	3.6	7.9	8.8	9.6	7.4	6.6	7.0	4.7	63.4
Quito,	T.	54.6	54.5	54.5	54.5	54.6	54.6	54.5	54.6	54.8	54.6	54.5	54.6	54.6
Ecuador	Rf.	4.1	4.2	5.1	7.4	5.0	1.5	0.8	1.4	2.9	3.6	3.7	3.8	43.5
Rio de Janeiro,	T.	77.5	78.1	77.2	74.1	70.7	68.2	67.5	68.7	69.4	71.2	73.4	74.8	72.5
Brazil	Rf.	5.0	4.3	5.3	4.4	3.5	2.0	1.6	1.8	2.6	3.2	4.3	5.4	43.4
Santiago,	T.	67.3	66.0	61.9	56.1	50.5	46.0	46.0	48.2	52.2	56.1	61.0	65.7	56.4
Chile	Rf.	0.0	0.1	0.2	0.6	2.6	3.3	3.1	2.2	1.3	0.5	0.2	0.2	14.3
Valdivia,	T.	61.9	60.4	57.9	53.1	49.6	45.5	45.7	46.4	48.0	52.0	55.0	59.0	52.9
Chile	Rf.	2.4	3.0	5.5	9.4	15.2	17.0	16.1	13.2	8.7	5.2	5.0	4.1	104.8

ANTARCTICA

Framheim (Little America)	T.	21.7	9.3	−7.4	−24.0	−27.0	−29.4	−33.7	−34.2	−29.2	−14.1	8.6	23.7	−11.3

EUROPE

Athens,	T.	46.4	47.5	52.3	58.8	67.8	75.7	80.6	79.9	73.9	66.0	57.0	50.0	63.0
Greece	Rf.	2.0	1.5	1.3	0.8	0.7	0.6	0.3	0.4	0.6	1.7	3.0	2.4	15.4
Berlin,	T.	31.3	32.5	37.0	45.9	54.9	62.1	64.6	63.3	57.0	48.2	38.1	32.7	47.3
Germany	Rf.	1.5	1.3	1.7	1.4	2.0	2.0	3.1	2.2	1.8	1.8	1.6	1.7	22.2
Bordeaux,	T.	40.6	43.2	46.9	53.1	58.3	64.2	68.2	68.2	63.7	55.4	46.9	41.2	54.1
France	Rf.	2.8	2.3	2.5	2.6	2.9	3.2	2.0	2.2	2.6	3.7	3.7	2.9	33.4
Bergen,	T.	34.2	33.6	35.4	42.1	48.9	55.0	57.9	57.6	52.7	45.1	38.5	34.7	44.6
Norway	Rf.	6.9	5.6	4.3	3.8	4.1	4.4	5.9	6.9	8.3	8.8	6.7	7.4	73.1
Brussels,	T.	34.4	36.1	39.7	46.9	53.2	59.7	63.0	62.2	57.7	49.5	41.2	35.6	48.2
Belgium	Rf.	2.2	1.8	2.0	1.7	2.3	2.5	3.1	3.1	2.7	2.9	2.7	2.6	29.6
Copenhagen,	T.	32.2	31.8	34.5	41.7	50.7	58.6	61.9	60.6	55.4	47.3	40.1	34.5	45.9
Denmark	Rf.	1.3	1.3	1.5	1.3	1.5	1.8	2.3	2.6	1.8	2.1	1.7	1.8	20.7
Dublin,	T.	42.1	42.5	43.6	47.0	51.8	57.1	60.1	60.0	56.0	50.2	45.8	42.7	49.9
Ireland	Rf.	2.3	1.9	1.9	1.9	2.0	2.0	2.6	3.0	1.9	2.7	2.7	2.5	27.4
Geneva,	T.	32.0	35.6	40.8	48.9	55.9	62.8	67.1	64.9	59.2	49.1	40.8	33.6	49.1
Switzerland	Rf.	1.6	1.8	2.1	2.6	3.2	3.0	3.1	3.5	3.1	4.4	3.1	2.2	33.7
Göteborg,	T.	30.7	30.4	33.1	41.7	50.7	59.0	62.2	60.6	54.9	46.0	38.5	32.7	45.0
Sweden	Rf.	2.6	1.9	1.9	1.5	1.9	2.1	2.9	3.2	3.5	3.0	2.9	2.6	30.0
Istanbul,	T.	40.6	41.0	45.5	52.3	61.0	69.1	73.2	72.5	67.3	61.3	52.5	45.3	56.8
Turkey	Rf.	3.4	2.7	2.4	1.7	1.2	1.3	1.1	1.7	2.0	2.5	4.0	4.8	28.9
Lisbon,	T.	50.5	52.2	54.3	57.6	60.3	66.7	70.0	71.1	68.4	62.2	56.5	51.6	60.1
Portugal	Rf.	3.6	3.5	3.4	2.5	1.9	0.7	0.1	0.2	1.4	3.2	4.3	4.0	28.8
London,	T.	38.9	40.1	42.4	47.3	53.4	59.2	62.7	61.6	57.1	49.9	44.0	40.3	49.7
England	Rf.	1.9	1.7	1.8	1.5	1.8	2.0	2.4	2.2	1.8	2.6	2.4	2.4	24.5
Lyon,	T.	36.3	40.1	45.9	54.0	60.3	66.4	70.2	68.5	62.6	53.2	43.7	36.5	53.1
France	Rf.	1.3	1.4	2.1	2.6	3.3	3.3	3.4	3.3	3.0	3.8	2.6	1.9	32.0
Madrid,	T.	39.7	43.9	47.5	52.3	59.4	68.5	75.7	74.8	66.4	54.9	47.1	40.1	55.9
Spain	Rf.	1.3	1.1	1.7	1.9	1.7	1.2	0.5	0.4	1.3	1.8	1.9	1.6	16.4
Moscow,	T.	12.2	14.7	23.4	38.3	53.1	61.5	66.0	62.8	52.2	39.7	27.7	17.2	39.0
U.S.S.R.	Rf.	1.1	0.9	1.2	1.5	1.9	2.0	2.8	2.9	2.2	1.4	1.6	1.5	21.0

TABLE IV. CLIMATIC DATA FOR SELECTED STATIONS (*Continued*)

EUROPE (*Continued*)

		Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Munich,	T.	27.3	30.4	36.1	45.3	53.1	59.7	63.0	61.5	55.4	46.0	35.6	28.6	45.1
Germany	Rf.	1.5	1.3	2.2	2.5	3.9	4.8	4.8	4.6	3.0	2.5	2.1	2.0	35.2
Odessa,	T.	25.3	27.7	34.9	47.5	59.2	68.0	72.7	70.9	62.1	51.8	41.0	30.6	49.3
U.S.S.R.	Rf.	0.9	0.7	1.1	1.1	1.3	2.3	2.1	1.2	1.4	1.1	1.6	1.3	16.1
Paris,	T.	34.9	39.4	43.2	49.3	56.1	61.7	64.6	63.9	58.5	50.0	42.4	38.1	50.2
France	Rf.	1.5	1.4	1.6	1.7	1.9	2.1	2.2	2.1	1.9	2.3	1.9	2.0	22.6
Rome,	T.	44.6	46.8	50.9	56.7	64.4	70.9	76.1	75.6	69.6	61.7	52.7	46.4	59.7
Italy	Rf.	3.2	2.7	2.9	2.6	2.2	1.5	0.7	1.0	2.5	5.0	4.4	3.8	32.5
Vienna,	T.	28.9	32.4	39.0	48.9	57.2	63.9	67.3	65.8	59.4	49.6	38.3	30.9	48.6
Austria	Rf.	1.5	1.3	1.8	2.0	2.8	2.8	2.8	2.8	1.7	1.9	1.6	1.7	24.5

AUSTRALIA AND NEW ZEALAND

		Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Adelaide,	T.	73.9	74.1	69.8	63.9	57.9	53.5	51.7	54.0	57.1	61.9	66.9	71.1	63.0
Australia	Rf.	0.7	0.6	1.0	1.7	2.8	3.1	2.6	2.5	2.0	1.7	1.2	1.0	20.9
Alice Springs,	T.	84.0	82.3	76.7	68.1	59.7	54.4	52.4	58.3	65.6	73.5	79.5	82.4	69.7
Australia	Rf.	1.8	1.7	1.3	0.9	0.6	0.6	0.4	0.4	0.4	0.7	0.9	1.3	11.1
Auckland,	T.	66.6	67.3	65.7	61.3	57.0	53.8	52.0	52.0	54.5	57.0	60.4	64.2	59.4
New Zealand	Rf.	2.6	3.0	3.1	3.3	4.4	4.8	5.0	4.2	3.6	3.6	3.3	2.9	43.8
Brisbane,	T.	77.2	76.5	74.3	70.3	64.5	60.2	58.5	60.4	65.4	69.8	73.6	76.4	68.9
Australia	Rf.	6.3	6.2	5.6	3.6	2.8	2.6	2.3	2.1	2.0	2.6	3.7	4.8	44.6
Darwin,	T.	83.8	83.4	84.0	84.1	81.8	78.9	77.4	79.4	82.6	85.3	85.8	85.1	82.6
Australia	Rf.	15.9	12.9	10.1	4.1	0.7	0.1	0.1	0.1	0.5	2.2	4.8	10.3	61.8
Melbourne,	T.	67.5	67.6	64.6	59.4	54.1	50.4	48.7	51.1	54.1	57.7	61.3	64.9	58.4
Australia	Rf.	1.8	1.8	2.1	2.2	2.1	2.0	1.8	1.7	2.4	2.6	2.2	2.2	24.9
Perth,	T.	73.5	74.1	71.1	66.4	60.4	56.2	55.0	55.9	58.0	60.9	65.4	70.6	64.0
Australia	Rf.	0.3	0.3	0.7	1.7	4.9	6.6	6.4	5.6	3.3	2.1	0.8	0.6	33.3
Sydney,	T.	71.7	71.3	69.3	64.7	58.8	54.6	52.7	55.0	59.2	63.5	67.1	70.1	63.1
Australia	Rf.	3.7	4.2	4.8	5.6	5.1	4.8	4.8	3.0	2.9	3.2	2.8	2.9	47.8

AFRICA

		Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Addis Ababa,	T.	61.9	59.4	64.0	61.2	63.2	59.2	56.7	58.9	58.0	60.0	61.4	60.0	60.2
Ethiopia	Rf.	0.6	1.9	2.8	3.4	3.0	5.7	11.0	12.1	7.6	0.8	0.6	0.2	49.6
Algiers,	T.	49.3	50.4	52.5	55.8	61.0	67.9	73.4	74.7	70.3	63.7	56.8	51.8	60.6
Algeria	Rf.	4.0	2.6	3.3	2.0	1.7	0.7	0.1	0.1	1.1	3.4	4.1	3.9	27.0
Banana,	T.	80.4	80.8	81.5	80.4	78.6	74.7	72.5	72.5	75.9	78.6	79.9	79.9	77.9
Belgian Congo	Rf.	2.1	2.3	3.7	6.1	1.9	0.0	0.0	0.1	0.1	1.6	5.9	4.7	28.6
Cairo,	T.	54.1	56.8	62.4	70.2	76.8	81.9	83.5	82.6	78.1	71.4	65.1	57.9	70.1
Egypt	Rf.	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	1.2
Cape Town,	T.	69.9	70.3	68.1	63.2	58.9	55.7	54.7	55.6	57.9	61.2	64.4	67.9	62.3
South Africa	Rf.	0.7	0.6	0.9	1.9	3.8	4.5	3.6	3.4	2.3	1.6	1.1	0.8	25.2
Freetown,	T.	81.3	82.3	82.4	82.4	81.5	80.3	78.6	77.9	79.1	80.1	81.2	81.4	80.7
Sierra Leone	Rf.	0.4	0.3	1.2	4.1	11.5	20.0	35.6	36.6	28.5	12.6	5.1	1.4	157.3
In Salah,	T.	54.0	57.0	66.2	76.5	85.3	93.7	97.7	95.0	90.0	80.2	67.6	57.2	76.6
Algeria	Rf.	....	....	....	....	....	....	....	....	....	....	....	....	....
Johannesburg,	T.	66.5	65.4	63.3	59.8	54.4	50.7	50.5	54.3	59.4	62.7	63.5	65.1	59.6
South Africa	Rf.	6.2	5.2	4.4	1.7	0.8	0.1	0.3	0.5	1.0	2.6	5.0	5.4	33.2
Lagos,	T.	80.9	82.2	83.3	82.5	81.8	79.3	78.0	77.7	78.4	79.5	81.4	81.5	80.5
Nigeria	Rf.	1.1	2.1	3.7	5.7	10.5	18.6	10.7	2.8	5.3	7.8	2.6	0.8	71.7

TABLE IV. CLIMATIC DATA FOR SELECTED STATIONS (*Continued*)

AFRICA (*Continued*)

		Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Port Elizabeth,	T.	69.4	69.7	68.0	65.1	61.6	59.3	57.9	58.4	59.8	61.8	64.5	67.6	63.6
South Africa	Rf.	1.2	1.3	1.8	2.0	2.4	1.7	1.9	2.1	2.2	2.1	2.1	1.7	22.5
Yaunde,	T.	73.6	73.9	73.6	72.3	72.1	70.9	70.2	70.7	71.1	70.7	72.3	73.0	72.0
Cameroon	Rf.	1.6	2.7	5.9	9.1	8.1	4.5	2.6	3.3	7.6	8.9	5.9	2.0	62.2

ASIA

		Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Baghdad,	T.	46.8	53.0	60.3	70.2	80.7	89.6	94.0	93.8	86.9	76.3	60.7	50.3	71.9
Iraq	Rf.	1.1	1.1	1.2	0.8	0.2	0.0	0.0	0.0	0.0	0.1	0.8	1.2	6.6
Batavia,	T.	77.9	77.9	78.1	79.5	79.7	79.2	78.6	79.0	79.7	79.9	79.3	78.4	78.9
Java	Rf.	13.0	12.8	7.8	5.1	4.0	3.7	2.6	1.7	2.9	4.5	5.5	8.5	72.1
Bombay,	T.	75.5	75.7	79.5	83.1	85.8	84.0	81.4	80.8	80.9	82.4	80.6	77.4	80.6
India	Rf.	0.1	0.1	0.0	0.0	0.7	19.9	24.2	14.5	10.6	1.9	0.4	0.0	72.4
Calcutta,	T.	66.6	71.2	80.2	85.6	86.1	85.1	83.7	83.2	83.2	79.3	73.5	66.5	78.7
India	Rf.	0.4	0.1	1.4	2.2	5.6	11.9	12.7	13.4	10.0	4.9	0.6	0.2	64.3
Delhi,	T.	57.9	62.2	74.1	86.2	91.7	92.2	86.4	84.5	83.9	78.5	67.6	59.6	77.1
India	Rf.	1.0	0.6	0.5	0.4	0.7	2.9	7.6	7.0	4.7	0.5	0.1	0.4	26.2
Karachi,	T.	65.3	68.4	75.0	80.6	84.7	86.8	84.3	82.4	82.0	80.0	74.0	67.4	77.6
India	Rf.	0.6	0.4	0.3	0.1	0.1	0.6	2.8	1.7	0.6	0.0	0.1	0.2	7.5
Madras,	T.	76.2	77.7	81.1	85.3	89.8	90.0	87.6	86.0	85.2	82.3	78.9	76.7	83.1
India	Rf.	1.1	0.3	0.3	0.6	1.8	2.0	3.8	4.5	4.8	11.1	13.6	5.3	49.2
Mukden,	T.	8.1	14.0	29.7	46.9	60.1	70.5	76.5	74.5	61.3	48.4	29.1	14.0	44.4
Manchukuo	Rf.	0.2	0.3	0.7	1.1	2.2	3.4	5.8	5.3	3.3	1.5	0.9	0.2	24.9
Manila,	T.	76.5	77.5	79.9	82.6	83.1	81.9	80.6	80.4	80.2	79.7	78.4	77.0	79.9
P. I.	Rf.	0.8	0.5	0.8	1.2	5.2	10.2	17.4	17.0	13.8	6.7	5.7	2.8	82.0
Nemuro,	T.	22.8	22.3	31.6	37.2	43.9	50.0	57.6	62.6	58.8	50.4	39.4	29.3	42.1
Japan	Rf.	1.3	1.0	2.2	2.9	3.7	3.7	3.8	4.3	5.5	3.8	3.3	2.3	37.8
Peiping,	T.	23.5	29.3	41.0	56.7	67.8	76.1	78.8	76.5	67.6	54.5	38.5	27.3	53.1
China	Rf.	0.1	0.2	0.2	0.6	1.4	3.0	9.4	6.3	2.6	0.6	0.3	0.1	24.9
Shanghai,	T.	37.6	39.2	46.0	56.3	65.5	73.4	80.4	80.2	72.9	63.3	51.8	42.1	59.0
China	Rf.	2.2	2.3	3.4	3.8	3.7	6.5	5.5	5.9	4.7	3.2	1.7	1.2	44.0
Singapore,	T.	78.3	79.0	80.2	80.8	81.5	81.1	81.0	80.6	80.4	80.1	79.3	78.6	80.1
Straits Setts.	Rf.	8.5	6.1	6.5	6.9	7.2	6.7	6.8	8.5	7.1	8.2	10.0	10.4	92.9
Teheran,	T.	33.6	42.3	48.1	61.3	71.3	80.0	84.9	83.2	77.4	65.8	51.3	41.7	61.7
Iran	Rf.	1.2	0.9	2.4	0.9	0.4	0.0	0.4	0.0	0.1	0.1	1.2	1.3	8.9
Tokyo,	T.	37.2	38.3	44.1	54.3	61.5	68.9	75.0	77.7	71.6	60.6	50.4	41.4	56.8
Japan	Rf.	2.0	2.6	4.3	5.3	5.9	6.3	5.6	4.6	7.5	7.2	4.3	2.3	57.9
Verkhoyansk	T.	−58.2	−48.1	−23.8	9.5	36.3	56.1	59.9	51.6	36.1	5.7	−34.1	−51.3	3.3
U.S.S.R.	Rf.	0.2	0.1	0.1	0.2	0.3	0.9	1.1	1.0	0.5	0.3	0.3	0.2	5.2
Vladivostok,	T.	4.8	12.4	26.4	39.2	48.7	56.8	66.0	69.4	61.3	48.6	29.8	13.6	39.7
U.S.S.R.	Rf.	0.1	0.2	0.3	1.2	1.3	1.5	2.2	3.5	2.4	1.6	0.5	0.2	14.7
Yakutsk,	T.	−45.9	−33.2	−9.2	16.7	41.4	59.5	66.4	58.8	42.6	16.7	−20.0	−40.4	12.8
U.S.S.R.	Rf.	0.2	0.2	0.1	0.2	0.5	1.1	1.3	1.7	0.9	0.5	0.4	0.3	7.4

TABLE V. THE CONTINENTS AND THEIR AREAS

Continent	Area in Square Miles	Continent	Area in Square Miles
Africa	11,297,377	Europe	3,780,103
Antarctica	5,362,626	North America	9,363,500
Asia	16,429,987	South America	7,049,646
Australia	2,974,581		

TABLE VI. SELECTED ISLANDS AND THEIR AREAS

Island	Area in Square Miles	Island	Area in Square Miles
Borneo, East Indies	282,416	Java, East Indies	50,745
Celebes, East Indies	72,679	Luzon, Philippines	40,814
Ceylon, Indian Ocean	25,332	Madagascar, Indian Ocean	228,707
Cuba, West Indies	44,164	Newfoundland, North Atlantic	42,734
Great Britain, North Atlantic	88,745	Novaya Zemlya, Arctic Region	35,150
Greenland, Arctic Region	837,620	Papua (New Guinea) East Indies	342,232
Hawaii, Pacific Ocean	4,015	Puerto Rico, West Indies	3,534
Hokkaido, Japan	30,000	Sicily, Mediterranean Sea	9,935
Honshu, Japan	87,500	Sumatra, East Indies	163,138
Iceland, Arctic Region	39,709	Vancouver, Canada	12,468
Ireland North Atlantic	31,829	West Spitzbergen, Arctic Region	15,260
Jamaica West Indies	4,450	Wrangel, Arctic Region	1,806

TABLE VII. SELECTED BODIES OF WATER AND THEIR AREAS

Body of Water	Area in Square Miles	Body of Water	Area in Square Miles
Antarctic Ocean	5,731,400	Huron Lake, U. S. A.	23,010
Arctic Ocean	5,541,000	Indian Ocean	28,357,000
Athabasca Lake, Canada	2,842	Manitoba Lake, Canada	1,817
Atlantic Ocean	31,529,000	Mediterranean Sea	1,145,000
Baikal Lake, U.S.S.R.	13,197	Gulf of Mexico	700,000
Balkash Lake, U.S.S.R.	7,115	Michigan Lake, U. S. A.	22,400
Caribbean Sea	750,000	Nyassa Lake, Africa	10,231
Caspian Sea	69,383	Ontario Lake, U. S. A.	7,540
Chad Lake, Africa	10,400	Pacific Ocean	63,985,000
Erie Lake, U. S. A.	9,940	Red Sea	178,000
Eyre Lake, Australia	3,700	Superior Lake, U. S. A.	31,810
Great Bear Lake, Canada	14,000	Tanganyika Lake, Africa	12,355
Great Salt Lake, U. S. A.	2,560	Titicaca Lake, South America	3,261
Great Slave Lake, Canada	7,100	Victoria Lake, Africa	26,828
Hudson Bay, North America	472,000	Winnipeg Lake, Canada	9,400

TABLE VIII. SELECTED RIVERS AND THEIR LENGTHS

River	*Length in Miles*	*River*	*Length in Miles*
Amazon, South America	3,900	Nile, Africa	4,000
Amur, Asia	2,900	Ob, Asia	3,200
Brahmaputra, Asia	1,800	Ohio, North America	1,283
Colorado, North America	1,650	Orinoco, South America	1,600
Columbia, North America	1,270	Paraná, South America	2,450
Congo, Africa	2,900	Plata-Paraguay, South America	2,300
Danube, Europe	1,725	Rhine, Europe	700
Euphrates, Asia	1,700	Rhone, Europe	500
Ganges, Asia	1,445	Rio Grande, North America	1,650
Hwang, Asia	2,700	Rio Negro, South America	1,400
Indus, Asia	2,000	St. Lawrence, North America	2,150
Lena, Asia	2,860	Saskatchewan, North America	1,205
Mackenzie, North America	2,500	Tapajóz, South America	1,150
Madeira, South America	1,200	Ural, Europe	1,400
Magdalena, South America	950	Volga, Europe	2,300
Mekong, Asia	2,600	Yangtze, Asia	3,100
Mississippi, North America	2,495	Yenisei, Asia	2,800
Missouri, North America	2,945	Yukon, North America	2,100
Niger, Africa	2,600	Zambezi, Africa	1,600

TABLE IX. LONGEST DAYS IN SELECTED LATITUDES

Latitude	*Length of Day*	*Latitude*	*Length of Day*
0°	12 hours	50°	16 hours, 9 minutes
5°	12 hours, 17 minutes	55°	17 hours, 7 minutes
10°	12 hours, 35 minutes	60°	18 hours, 30 minutes
15°	12 hours, 53 minutes	65°	21 hours, 9 minutes
20°	13 hours, 13 minutes	66° 33'	24 hours
25°	13 hours, 34 minutes	70°	65 days
30°	13 hours, 56 minutes	75°	103 days
35°	14 hours, 22 minutes	80°	134 days
40°	14 hours, 51 minutes	85°	161 days
45°	15 hours, 26 minutes	90°	6 months

In the above tabulation, the longest day is considered the longest period from sunrise to sunset. Further, no allowance is made for the slower rotation of the earth on its axis during the summer months nor for refraction, which lengthens the daylight period everywhere.

TABLE X. LAND AND WATER AREAS OF THE UNITED STATES BY STATES—1940*

Area	*Total Area in Square Miles*	*Land Area in Square Miles 1940*	*Inland Water Area in Square Miles*
United States	3,022,387	2,977,128	45,259
Alabama	51,609	51,078	531
Arizona	113,909	113,580	329
Arkansas	53,102	52,725	377
California	158,693	156,803	1,890
Colorado	104,247	103,967	280
Connecticut	5,009	4,899	110
Delaware	2,057	1,978	79
District of Columbia	69	61	8
Florida	58,560	54,262	4,298
Georgia	58,876	58,518	358
Idaho	83,557	82,808	749
Illinois	56,400	55,947	453
Indiana	36,291	36,205	86
Iowa	56,280	55,986	294
Kansas	82,276	82,113	163
Kentucky	40,395	40,109	286
Louisiana	48,523	45,177	3,346
Maine	33,215	31,040	2,175
Maryland	10,577	9,887	690
Massachusetts	8,257	7,907	350
Michigan	58,216	57,022	1,194
Minnesota	84,068	80,009	4,059
Mississippi	47,716	47,420	296
Missouri	69,674	69,270	404
Montana	147,138	146,316	822
Nebraska	77,237	76,653	584
Nevada	110,540	109,802	738
New Hampshire	9,304	9,024	280
New Jersey	7,836	7,522	314
New Mexico	121,666	121,511	155
New York	49,576	47,929	1,647
North Carolina	52,712	49,142	3,570
North Dakota	70,665	70,054	611
Ohio	41,222	41,122	100
Oklahoma	69,919	69,283	636
Oregon	96,981	96,350	631
Pennsylvania	45,333	45,045	288
Rhode Island	1,214	1,058	156
South Carolina	31,055	30,594	461
South Dakota	77,047	76,536	511
Tennessee	42,246	41,961	285
Texas	267,339	263,644	3,695
Utah	84,916	82,346	2,570
Vermont	9,609	9,278	331
Virginia	40,815	39,899	916
Washington	68,192	66,977	1,215
West Virginia	24,181	24,090	91
Wisconsin	56,154	54,715	1,439
Wyoming	97,914	97,506	408

* After the U. S. Census, 1940.

Based on a set of U. S. Coast and Geodetic Survey aeronautical charts on a scale of 1:500,000. Areas computed by use of international geodetic tables and planimeter measurement.

"Land area is defined to include: Dry land and land temporarily or partially covered by water, such as marshland, swamps, and river floodplains; streams, sloughs, estuaries, and canals less than one-eighth of a statute mile in width; and lakes, reservoirs, and ponds having less than 40 acres of area."

"Inland water is defined to include: Permanent inland water surface, such as lakes, reservoirs and ponds having 40 acres or more of area; streams, sloughs, estuaries, and canals one-eighth of a statute mile or more in width; deeply indented embayments and sounds; and other coastal waters behind or sheltered by headlands or islands separated by less than one nautical mile of water; and islands having less than 40 acres of area."

INDEX

"A" or tropical climates, 637ff.
Abaca, 461.
Absolute humidity, statement of, 128.
Achua, 375.
Acre-foot, a measure of irrigation water, 214.
Admiralty mile, 613.
"Af" or tropical rain forest climate, 637ff.
Agassiz, Lake, origin and drainage of, 262f.
Agriculture, advantages of rice as a crop in Oriental, 415f.; animal industries of Oriental, 424f.; annual range of temperature, effect on, 122f.; beginnings of, 397ff.; 413f.; character of advance of, 413f.; characteristics of Oriental, 414f.; classification of types of Occidental, 433; cloudiness, effect on, 139; commercial grain farming, 436ff.; daily range of temperature, effect on, 121f.; dairying, 440ff.; diversification of, 435ff.; dry farming, 437f.; effectiveness in producing environmental change, 101f.; elevation, effect on, 122ff.; evolution of present day Occidental, 430ff.; farm size and pattern in Oriental, 420ff.; frost and crops, 119ff.; frost-free season, effect on, 116ff.; garden, 442ff.; general farming, 434ff.; high temperatures, effect on, 118; Indian, 407f.; intensity of precipitation, effect on, 143; Japanese, 419ff.; Javanese, 418ff.; location of frontiers of, 413; mechanization of, 439f.; modification of environment by, 413ff.; Oriental, 413ff.; Oriental in Japan, 419ff.; origin of Occidental, 429ff.; origin of animals of Occidental, 430f.; origin of crops of Occidental, 430ff.; patron divinities of, 492; pattern of early western European, 432ff.; plantation, 447ff.; primitive, 397ff.; problems of Japanese, 425ff.; semiplantation, 461f.; soil groups as they affect, 665f.; specialized intensive, 422ff.; spread of Occidental, 429f.; subsistence, 433ff.; sunlight, effect on, 115f.; temperature efficiency, effect on, 117f.; types of Occidental, 432ff.; types of Oriental, 415; types of plantation, 450f.; use of fertilizer in Oriental, 423f.
Agricultural regions, United States, 664.
Ainu, 419f.
Air, ability of to hold water, 126f.; masses, 651; air mass analysis, 652f.; transport by, 532f.; effects of transport by, 536ff.; speed of transport by, 535f.
Aithoff's projection, 603f.
Alakalufs, a nomadic hunting population, 369.
Alaska, fisheries of, 506ff.; gold mining of, 483ff.; strategic importance of, 22; value of, 22f.
Aleppo pine, a forest product, 474.
Alexander, contributions to geographic knowledge by, 4.
Alkali spots, 97ff.
All-American Canal, 221.
Alluvial fans, 257.
Alluvial plains, city sites on, 26f., 259; farm pattern of, 259f.; floods of, 259ff.; formation of, 257f.; natural drainage of, 257f.; soils of, 257f.; topography of, 257f.; variation in, 259f.
Alluvium, deposition of, 176f.; productivity of, 176f.
Amana villages, 562f.
Amazon River, use of for navigation, 184.
Ambergris, 500.
Anemometer, 148.
Animal life, 345ff.; desert, 346f.; forest, 345ff.; grassland, 346f.; man's domestication of, 346f.; man's modification of, 346ff.; tundra, 346f.
Annapolis Cornwallis Valley, 444.
Ann Arbor, water supply of, 231f.
Anticyclones, 154f.; paths of travel of, 165.
Antipodal location, 350.
Area, how shown on maps, 599; land, United States, 683; total, United States, 683; water, United States, 683.
Areal differentiation, effect of stage of development on, 26f.
Aristarchus, 627.
Aristotle, 2.
Arkansas, irrigation in, 214.
Artesian wells, 231.
Asari, a Hokkaido fishing village, 508ff.
Asia, soil erosion in, 112.
Asteroids, 627.
Atacama Desert, nitrate deposits of, 304f.
Atlantic and Gulf Coastal Plain, elevation and topography of, 253f.
Atmosphere, layers of, 160f.; thickness of, 160f.
Australia, precipitation of, 62.
Automobiles, development of, 528ff.; effect of on other forms of transportation, 530f.
"Aw" or savanna climate, 640ff.
Azimuthal projections, 600; equidistant, 604f.
Aziza, temperatures of, 118.

"B" or dry climates, 647ff.
Babinet's equal-area projection, 602f.
Baguio, 154.
Balia, African pygmies, 376.
Banana, cultivation of, 451f.; plantations, 450ff.

Banks, Newfoundland, 503f.
Barge Canal, New York State, 195ff.
Barometer, 162f.; use of in weather prediction, 162f.
Base line, 626.
Basin furrowing, 110.
Bay of Fundy, tides of, 311.
Beasts of burden, use of animals for, 515ff.
Belém, rainfall of, 161; temperatures of, 123.
Belterra, a rubber plantation, 458.
Beluga, 367.
Bermudas, water supply of, 226.
Bhils, 251.
Bikei, 400.
Black fellows, 63.
Blizzard, 158.
Bluegrass, settlement of, 60f.
Bog ores, 294.
Bonne projection, 610.
Bora, 61, 151.
Boston, city plan of, 571; water supply of, 230.
Boulder, water supply of, 232.
Bronze, use of, 291f.
Brown soils, 663ff.
"BS" or steppe climate, 647ff.
Bucher, 373.
Building stone, 303f.
Bush fallowing, Nigeria, 401f.
Bushmen, 31; adaptations to the desert, 374ff.; clothing and utensils of, 372ff.; food supply of, 373ff.; home of, 369f.; method of kindling a fire by, 373; physical characteristics of home region of, 369ff.; shelters of, 372f.
Bush Negroes, 401ff.
"BW" or desert climate, 648ff.

"C" or Mesothermal climates, 641ff.
Calendars, 632ff.
California, attenuation of, 356f.; coastal fogs of, 137; grazing as an economic activity in, 395f.; irrigation in, 221ff., 224ff.; population change in, 47f.
Camel, use of as beast of burden, 516.
Campos region, 391, 641.
Canada, access to sea of, 323f.; attenuation of, 358f.
Canals, early, 525; early in the United States, 194ff.; eastern Asia, 200f.; European, 198ff.; navigation of, 194ff.
Capital, industrial development as affected by, 546f.
Caribou, migration of, 117.
Caribbean, strategic problems of, 355f.
Carthage marble, 274.
Carts, use of, 518f.
Cassava, 406.
Cattle, grazing of, 395ff.
Censuses, past and present, 11ff.
Central Valley Project, 224ff.; objectives of, 224f.
"Cfa(Cw)" or humid subtropical climates, 641ff.
"Cfb" or marine west coast climate, 643ff.
Chaparral, 332.
Chariots, use of, 519f.
Charleston, growth of, 566.
Chernozem, 662ff.
Cherrapunji Valley, maximum precipitations of, 143.
Chestnut soils, 663ff.
Chicago, dust in air of, 133; site of, 500.
Chile, attenuation of, 52.
China, coal deposits of, 482; fisheries of, 502; industrial development of, 550; industry of, 543f.; loess deposits of, 178; monsoon winds of, 151ff.; population problems of, 45f.; roads of, 524f.; soil erosion in, 112; use of waterways in, 238.
Chinook, 158.
Cincinnati, city site and plan of, 569; growth of, 566.
Cirrus clouds, 137.
Cisterns, use of, 229f.
Cities, 558; "blighted" sections of, 572; classes of, 562; United States colonial, 561f.; commercial, 562f.; congestion in, 572; factors affecting growth of, 566ff.; functions of, 561; future of, 583ff.; governmental, 564f.; growth of large American, 574ff.; industrial, 564f.; large cities of recent development, 561f.; location of, 558f.; locations favoring development of, 559ff.; locational advantages of, 351ff.; mining, 566f.; obsolescence in, 572; plans of, 568ff.; problems of, 571ff.; residential, 565f.; resort, 565f.; sites of, 560f.; suburban developments of, 581f.; variable values of a location for, 560ff.
Clay, use of, 303f.
Climate, basis for classification of, 168f.; classification of, 637ff.; major subdivisions of, 637f.; life forms as affected by, 114f.
Climatic conditions, effects of, 52ff.
Climatic data, selected stations, 676ff.; Antarctica, 678; Europe, 678, 679; Asia, 680; Australia and New Zealand, 679; North America, 676, 677; South America, 677, 678.
Climatic types, 637ff.
Cloquet fire, 83.
Clouds, effects of on man, 139f.; names of, 137f.
Coal, 295ff.; advantageous distribution of, 298f.; ease of mining of, 295f.; 296; origin of, 295f.; periods of formation of, 295f.; U.S.S.R., 494; world production of, 296f.; world resources of, 296f.; types of, 295f.
Coal Age, 298f.
Coal-mining communities, 485ff.
Coasts, 318ff.; change along, 315f.; depressed, 316f.; elevated, 317f.; erosion and sedimentation along, 317f.
Coastal plains, Atlantic, elevation of, 253; cutover land problems of, 255; economic activities of, 255ff.; formation of, 253f.; natural drainage of, 254f.; resort business of, 257; soils of, 254ff.; urban development of, 257; variation in, 254f.
Collectives, U.S.S.R., 439.
Colloids, 173.
Colorado plateaus, 274f.; economic activities of, 276f.; elevation and extent of, 274f.; population of, 276f.; precipitation of, 276f.; relief of, 274ff.; temperatures of, 276f.
Colorado River, fluctuations of, 207ff.; improvement of, 243ff.; use of for irrigation, 212f.; use of for power development, 210ff.
Columbus, voyages of, 6f.
Commerce, 539ff.; basis for, 539ff.; cultural differences affecting, 540f.; employment afforded by,

542f.; sea-borne, 540f.; transportation affecting, 540f.
Conformal projections, 600.
Conic projections, 607f.; tangent cone, 607f.; secant cone, 608f.
Coniferous forest, 331ff.; middle latitudes, 332f.; subarctic, 332f.
Conservation, steps necessary for mineral wealth, 495ff.
Continents, areas of, 681; locational advantages of, 350f.
Continental shelf, 308f.
Continental slope, 308f.
Contour interval, 621f.
Contour line, 621f.
Contour plowing, 110.
Copernicus, 627.
Copper, occurrences of, 302.
Corials, 404.
Cork, sources of supply of, 474.
Corn, water requirements of, 214.
Cortez, 22.
Cosmas, map, 2.
Cosmography, Christian, 3f.
"Cs" or Mediterranean climate, 642ff.
Coulee Dam project, 210ff.; effect of on fisheries, 506.
Counties, compact and attenuated, 356f.
Countries, compact and attenuated, 358f.; handicaps of small size of, 361f.; locational advantages of, 351f.; small, 361ff.
Crater Lake, 287.
Crops, plantation, 449ff.; rotation of, 174f.; variation in water requirements of, 214; water requirements of, 214ff.
Cryptomeria, 474.
Cuba, sugar production of, 453ff.
Cultural environment, factors of, 52ff.; man as affected by, 63ff.
Cumulus clouds, 137.
Currents, effect of ocean on temperatures, 312f.
Cutover lands, coastal plains, 255; problems of, 475ff.
Cuyuna range, 490.
Cyclones, 154f.; origin of, 163f.; paths of travel of, 163f.; structure of, 651.
Cylindrical equal-area projection, 601f.
Cypress, 471.

"D" or Microthermal climates, 643ff.
Dairy farming, 440ff.; animal industries of, 441ff.; crops grown in, 441ff.
Date line, 635ff.
Daylight period, variation in length of, 628ff.
Days, lengths of in hours, 682.
Death Valley, temperatures of, 118, 130.
Deccan, lava flows of, 69.
Deciduous hardwood forest, 330f.
Declination, compass, 618ff.
Deeps, 309f.
Deforestation, an agency of environmental change, 78ff.
Degradational plains, origin of, 267f.; soils of, 267; variation in, 270.
Demersal fisheries, 499.
Desert or "BW" climate, 648ff.
Deserts, plant communities of, 328f.; soils of, 665f.; subtropical high regions, 161; trade wind regions, 161; types of, 114; vegetation of, 341ff.
Destructive winds, 154ff.
Detroit, city site and plan, 571f.; effect of automobile on growth of, 530f.; growth of, 561, 567; suburban development of, 583f.
Developable surfaces, 599f.
Dew, 139ff.; conditions favoring occurrence of, 140.
Dew point, 129.
"Dfa(b)" and "Dwa(b)" climates, 644ff.
"Dfc" and "Dwc" climates, 645ff.
Direction, how shown on maps, 599; on maps, 618f.
Dissected plateaus, 276ff.; drainage of, 276f.; economic activities of, 279f.; elevation of, 276ff.; living conditions in, 279f.; settlement of, 276ff.; topography of, 276f.; variation in, 279f.
Distance, how shown on maps, 599.
Diversified agriculture, 435ff.; animal industries of, 435ff.; characteristics of, 435ff.; crops of, 435ff.; desirability of, 436f.
Djuka, 401ff.; clothing of, 404f.; collecting industries of, 406f.; flora and fauna of area occupied by, 402f.; food supply of, 405ff.; future of, 406f.; houses and furnishings of, 404ff.; hunting and fishing by, 406f.; origin of, 401f.; physical conditions of area occupied by, 402ff.; territory occupied by, 401; tribes of, 402; villages of, 402f.
Doldrums, 148.
Donets basin, 547.
Donkey, use of as beast of burden, 515f.
Drainage, advantages and disadvantages of, 88ff.; associated with irrigation, 86; benefits from artificial, 246f.; conditions under which beneficial, 88f.; conditions under which desirable, 247f.; detrimental effects of, 246; economic aspects of artificial, 246f.; effectiveness in producing environmental change, 101f.; effects of artificial, 246ff.; irrigated areas, 246; lake levels as affected by, 88; Netherlands, 83ff.; problems of artificial, 244ff.; wild life as affected by, 88f.
Drained land, classes of in the United States, 86f.; distribution of in the United States, 87.
Drive wells, 229f.
Droughts, damage produced, 227f.; definition of, 70; intensification of detrimental effects by unwise use of the land, 71f.
Dry or "B" climates, 647ff.
Dry blizzards, 107.
Dry cold, its effect on sensible temperatures, 130.
Dry farming, hazards of, 393, 437ff.
Duluth, city expansion of, 568; water supply of, 233f.
Dunes, 176f.
Dust, amount of in the atmosphere, 133ff.; composition of atmospheric dust, 132; effects of on atmospehirc phenomena, 133f.; function of in condensation of atmospheric moisture, 133; origin of atmospheric, 132f.; variability in amount of atmosperic, 133.
Dust Bowl, 70, 102; erosion in, 173f.
Dust storms, 93; effect of relative humidity on prevalence of, 132.

"E" or polar climates, 646ff.
Earth, dimensions of, 612ff.; early beliefs as to extent of inhabited, 1f.; early beliefs as to shape and size of, 1f.; equatorial diameter of, 613; Greek concepts of shape and size of, 1ff.; inclination of axis of, 627; measurements of, 612f.; orbit of, 627; polar diameter of, 613; revolution of, 627f.; rotation of on axis, 627f.; size and shape of, 612f.
Earthquakes, 66ff.; causes of, 66f.; effects of, 67f.; important, 66f.; regions of occurrence of, 66f.
Earthworms, work of, 75f.
Ebony, 466.
Economic activities, environmental effects of, 55ff.
Economic organization, environmental effects of, 56f.
Ecumene, 358.
Eden shale belt, 268f.
Egypt, irrigation in, 216f.
Elephants, use of as beasts of burden, 516f.
Elevation, native vegetation and crops as effected by, 123f.; temperatures as effected by, 123f.; representation of on maps, 621f.
El Ued, 55.
England, soil erosion in, 111.
Environment, agencies producing slow change in, 76f.; alteration of by man, 21f.; alteration of by civilized man, 21f.; alteration of by primitive man, 21f.; American pioneers as affected by 23ff.; change in by plants and animals, 74ff.; changing views of values of, 22ff.; functions of, 18ff.; human agencies effecting change in, 78f.; lack of stability of, 20f.; life forms as affected by, 325ff.; limiting effects of, 19f.; man's effects on cultural, 63ff.; natural agencies producing change in, 66f.; permits progress if favorable, 59ff.; poor as a cause of retardation, 60ff.; present-day views as to desirability of, 24f.; primitive man as affected by, 22f.; repressive as it affects man, 62ff.; stage of development as it affects values of, 21ff.
Environmental change, human agencies producing, 101ff.; natural agencies producing, 78ff.
Equal-area projections, 600.
Equidistant projections, 604f.
Equinoxes, 628.
Eratosthenes, 3, 5, 6, 591.
Erie Canal, 194ff., 526.
Erosion, agency of environmental change, 76; beginnings of in the United States, 171f.; climatic effects on, 172f.; conditions favoring, 171ff.; crop yields as affected by, 173f.; slope as it affects, 172f.; soil type as it affects, 171f.; United States as affected by, 172ff.
Eskimo, 31; areas occupied, 364f.; modification of life of by contact with whites, 365f.; sources of support of, 364f.
Estonia, 361.
"ET" or tundra climate, 646ff.
Europe, industrial regions of, 547ff.; population and population changes in, 42ff.; probable post-war pattern of industry of, 549f.; spread of population of, 44ff.
Evaporation, factors affecting, 129; rate of, 129f.
Everglades, 253; fires of, 83f.
Evergreen hardwood forest, 328f.
Exports, relation of to imports, 540f.
Extractive industries, characteristics of, 94f.; effectiveness of in producing environmental change, 101f.
Eyre, Lake, 62.

Fallwinds, 149f.
Fang, 38; agriculture of, 398ff.; clearing for planting by, 398f.; clothing and utensils of, 400ff.; collecting industries of, 400f.; crops of, 398; domestic animals of, 399f.; economic activities of, 398ff.; fishing by, 399f.; homeland of, 397f.; hunting by, 400f.; migrations of, 401ff.; physical conditions of area occupied by, 397ff.; settlements of, 400ff.
Farms, size and patterns of in Japan, 420ff.
Fauna, desert, 346f.; forest, 345ff.; functions of, 53f.; grassland, 346f.
Fens, 178.
Fertilizers, 303ff.
Feterita, 430.
Finland, forest industries of, 475.
Fires, records of early forest, 74f.; set by lightning, 74f.; set by man, 81f.
Fisheries, Alaskan, 504ff., 506ff.; Atlantic and Gulf, 504; demersal, 499; depletion of, 504ff.; eastern Asia, 502f.; future of, 512ff.; inshore, 499; lake, 506f.; location of, 499f.; Newfoundland, 510ff.; North Atlantic of the United States, 503ff.; northwestern Europe, 501ff.; Pacific coast, 504ff.; pearl, 499f.; pelagic, 499; regulation of, 513f.; salmon, 504ff.; tropical, 499f.; types of, 499f.; value of, 499f.
Fishing, 498ff.; recreational, 238; subsistence, 238.
Fishing grounds, location of, 501f.
Flint, use of by early man, 291f.
Floating populations, 238.
Floods, boundary disputes resulting from, 69; causes of, 69f., 244f.; control of, 245ff.; deposition during, 69f.; effects of, 69ff.; losses from, 245f.; man's activities and their effects on, 244ff.; probability of in different areas, 245f.
Flood water farming, 410.
Flora, effects of, 53f.
Florida, resort business of, 257.
Foehn, 158.
Fogs, areas of in the United States, 137; areas of dense, 137f.; cause of, 135f.; dispersal of, 137; economic importance of, 137f.; efficiency and health as affected by, 137; falling of, 135; navigation of air as affected by, 137; ocean navigation as affected by, 137; rising of, 135; seasons of occurrence of, 135f.; summer, 136.
Ford rubber plantation, 358ff.; sale of, 460.
Fordlandia, 458.
Forests, clearing of for agriculture, 464ff.; collecting stage of use of, 464ff.; coniferous, 330f., 331ff.; deciduous hardwood, 328f.; destruction of, 81ff.; evergreen hardwood, 328f.; use of as mine or crop, 475ff.; plant communities of, 327f.; removal of as it affects precipitation efficiency, 82; repressive effects of on early man, 463f.; scrub and thorn,

330ff.; swamp, 336f.; types of as affected by water supply, 328f.; variable value of, 463ff.
Forest fires, effects of, 83ff.; examples of, 83ff.; number and distribution of in the United States, 82ff.; relative humidity as it affects prevalence of, 132; soils as affected by, 83.
Forest industries, Africa, 474f.; Asia, 474ff.; Canada, 473f.; early in the United States, 467f.; Europe, 475ff.; far west in the United States, 472ff.; intermediate latitudes, 467f.; northeastern United States, 467f.; South America, 473f.; southeastern United States, 471ff.; taxation of, 477ff.; tropics, 466ff.
Friant Dam, 224.
Fronts, 651ff.
Frosts, 140; average dates of killing for the United States, 669; average dates of first killing in fall for the United States, 670; average dates of last killing in spring for the United States, 669; prevention of, 121f.; protection of crops from, 118ff.
Frost-free season, average length of for the United States, 669; effective length of for the United States, 117; length of as it affects agriculture, 116ff.
Fruit growing, 441f.
Fuji, 285.
Fulani, 392.
Fur seals, 500.

Galapagos Islands, 351.
Call's stereographic projection, 601f.
Galveston flood, 72, 311.
Gennakens, 375.
Geographical poles, 618.
Geography, dark ages of, 3ff.; fields of, 1f., 6f., 7f.; present day, 6f.; renaissance of, 1f.; types of, 7f.
Glacial plains, handicaps to land use of, 262f.; natural drainage of, 261f.; origin of, 260f.; soils of, 260f.; topography of, 260f.
Glaciated highlands, 279ff.; economic activities of, 282f.; elevation of, 280f.; forest cover of, 280f.; natural drainage of, 280f.; opportunity in, 282ff.; origin of, 279f.; roads of, 282f.; soils of, 280f.
Glaciation, in the United States, 663.
Globular projection, 606.
Gnomonic projection, 605f.
Gold, occurrences of, 302; mining of in Alaska, 483ff.
Gonds, 251.
Government, population as affected by, 19ff.
Governmental cities, 564f.
Government power projects, 212f.
Grand Canal, China, 525.
Grand Canyon, 274.
Grasslands, animal life of in the United States, 90; cause of, 90f.; conditions favoring, 338f.; effects of man's invasion of, 92ff.; extent of, 90f.; intermediate latitudes, 339ff.; man's invasion of in the United States, 90ff.; man's modification of, 93ff.; marsh, 341f.; opportunity afforded for grazing by, 92ff.; plant communities of, 328f.; prairie, 339f.; tropical, 339f.; types of in the United States, 90f.; vegetation of in the United States, 90.
Gray brown and brown forest soils, 659ff.
Grazing, commercial, 389ff.; commercial in Africa, 391ff.; commercial in California, 395f.; commercial in Mediterranean areas, 395f.; commercial in South America, 391ff.; commercial in steppe grasslands, 392ff.; commercial in tropical grasslands, 390ff.; contrasts between commercial and nomadic, 390ff.; decline in relative importance of, 395f.; nomadic, 380ff.; types of areas where practiced, 389ff.
Great Circle, definition of, 350.
Great Dismal Swamp, 253.
Great Lakes, factors favoring use of for transportation, 191ff.; harbors of, 193f.; passenger traffic on, 193; ports of, 193ff.; terminal facilities of ports of, 193f.
Great Plains, vegetation of, 392ff.; wind erosion, 105.
Greece, soil erosion in, 111.
Gregorian calendar, 632.
Ground water, 226ff.; as affected by drainage, 88; effects of, 53f.; effects of drought on, 227f.; handicaps of hardness of, 226f.; high sulphate, 227; Lake Agassiz Plain, 227; mineralization of, 226ff.; variation in quality of, 227f.
Gulf Stream, 312.
Gullying, areas of occurrence of, 102; attention attracted by, 103f.
Gunyah, 62.

"H" or highland climates, 648ff.
Hachures, 621.
Hail, formation of, 142; losses from, 142ff.
Han cities, 560.
Hankow, location of, 560.
Harbors, characteristics and origin of, 317f.; of Great Lakes, 193.
Hard water, 226; tolerable hardness of, 226f.
Hazard, a coal-mining community, 485ff.
Headward erosion, 103.
Hecataeus, 4.
Hematite, 294.
Hemispheres, Land and Water, 350; locational advantages of, 349f.; People's, 9.
Hereford map, 3.
Herodotus, 6; contributions to geographic knowledge by, 4; map by, 591.
Hevea brasiliensis, 454; growth in native home of, 458; transfer of to southeastern Asia, 458.
Hibbing, 489ff.
Hibernation, 117.
Highland or "H" climates, 648ff.
Highlands, 272ff.; common characteristics of, 272f.; desirability of for human habitation, 124ff.; handicaps of, 124f.; mineralization of, 301f.; opportunity for man in, 272f.; types of, 272f.
High plateaus, 274ff.
Highways, development of, 520ff.
Hinckley fire, 83.
Hogans, 387.
Hokkaido, agricultural occupation of, 419f.; fisheries of, 506f.; fogs of, 137.
Homolographic projection, 602f.
Homolosine projection, 603f.
Hoover Dam Project, 209ff.; objectives of, 243f.
Hopi Indians, 407ff.; agriculture and food supply of, 409ff.; animals of, 411f.; crops grown by, 410f.;

economic activities of, 411f.; houses of, 409f.; location and extent of area occupied by, 407f.; villages of, 408f.; water supply of, 409f.
Horse, use of as beast of burden, 515f.
Houses, types of as affected by environment, 53ff.
Houston, ship canal of, 198.
Hudson Bay Company, 464.
Hull-Rust mine, 489.
Humboldt, Cosmas, 6.
Humid continental or "Dfa(b)" and "Dwa(b)" climates, 644ff.
Humid subtropical or "Cfa(Cw)" climates, 641ff.
Humidiguide, 129.
Humus, 170f.
Hurricanes, 154ff.; energy developed by, 72; floods produced by, 72; regions of occurence of, 72f.
Hwang, floods of, 69, 112; handicaps to use of for navigation, 186.
Hydroelectric power, 202ff.; benefits of to man, 213f.; costs of generation of, 202; distribution of potential and developed, 204ff.
Hydrosphere, 160.
Hygrometer, 129.

Ice supply, 238.
Iceland, fisheries of, 501.
Igloo, 366.
Iglooyak, 366.
Illinois, relative importance of mining in, 482; value of mineral production of, 482.
Illinois and Michigan Canal, 195f.
Illinois and Mississippi Canal, 198f.
Immigration, to Canada, Australia, and New Zealand, 44; to the United States, 44.
Imperial Canal, 221; use of water from, 221f.
Imperial Dam, 221.
Imperial Valley, 217; crops of, 221; irrigation in, 218ff.; origin of, 218.
Incas, 22.
India, industrial development of, 550; irrigation in, 216f.; monsoon winds of, 151f.; population of, 14; population increase in, 42; population problems of 45ff.
Indian agriculture, 407f.
Indiana, population change in, 47f.
Indoor relative humidity, unfavorable effects of, 131f.
Industrial areas, Europe, 547ff.; Japan, 549f.; Orient, 549ff.; United States, 550ff.; post-war United States, 556f.
Industrial water supply, 233ff.
Industry, beginnings of, 542ff.; capital as affecting development of, 546f.; culture of population as affecting character of, 546f.; extensive development of recent, 546f.; factors affecting location of, 543f.; future of in the United States, 556ff.; government as affecting development of, 546f.; human choice as affecting development, of, 544f.; labor supply as affecting development of, 545ff.; location of as affected by water supply, 236ff.; markets as affecting development of, 546f.; miscellaneous factors affecting development of, 545; other economic activities as affected by, 543f.; raw materials affecting development of, 544ff.; transportation as affecting development of, 543f.; water supply affecting development of, 545ff.; zoning of, 555ff.
Inland waters, miscellaneous uses of, 238ff.; recreational use of, 238ff., 240.
Inner Bluegrass, 268f.
Insects, damage by, 347ff.
Inshore fisheries, 499.
Intermediate latitudes, forest industries of, 467f.
International Date Line, 635ff.
International map of the world, 597f.
Interrupted homolosine projection, 603ff.
Ionosphere, 160.
Iowa City, water supply of, 231f.
Iron, early use of, 292ff.; use of by civilized man, 294f.
Iron Age, 298f.
Iron ores, 294ff.; advantageous distribution of, 298f.; areas of important occurrences of, 294f.; future of in Minnesota, 494; Minnesota resources of, 489f.; reserves of United States, 294ff.
Iron and steel industry, development of, 546ff.; factors affecting location of, 547f.
Irrigation, arid and semiarid regions, 215ff.; conditions under which practiced, 214ff.; detrimental effects of, 96ff.; distribution of by drainage basins in the United States, 217; economic soundness of Federal projects, 218; effectiveness of in promoting environmental change, 101f.; Egypt, 216f.; factors affecting desirability of, 99ff.; favoring topography for, 215; Federal projects, 218f.; garden crops of, 214f.; history of development of in western United States, 218ff.; humid areas, 214ff.; Imperial Valley, 218ff.; importance of ground water in, 218; importance of surface waters in, 218; India, 216f.; Mediterranean areas, 216f.; ownership of enterprises in the United States, 218ff.; possibilities for expansion of, 224ff.; sources of water for, 218ff.; western United States, 217ff.; types of projects, 95f.
Islands, areas of, 681; locational advantages of, 351ff.
Isobars, 153; of weather maps, 162.
Isotherms, 115; paths of and factors affecting, 116f.

Jaguar, 402.
Japan, agricultural practices in, 423ff.; agricultural problems of, 425ff.; animal industries of, 424f.; crops of other than rice, 423f.; farm sizes and patterns of, 420ff.; fertilizer use in agriculture, 423f.; fisheries of, 502ff.; industrial regions of, 549f.; introduction of rice as crop in, 419f.; irrigation in, 214f.; islands and latitudinal extent of, 419f.; Oriental agriculture in, 419ff.; population problems of, 45f., 427ff.; soil erosion in, 112.
Java, example of the ricelands, 418ff.; population of, 9.
Julian calendar, 632.

Kafir corn, 430.
Kaffirs, 392.
Kalahari, 31; precipitation of, 370ff.; surface of, 369f.; temperatures of, 369f.; wild life of, 372f.; vegetation of, 371f.

Kaross, 373.
Karroo, 392.
Kavak, 367.
Kelp, 321.
Kentucky Mountains, 276ff.; settlement of, 61f.
Kentucky River, improvement of for navigation, 189f.
Key West, sponge fisheries of, 499.
Kickapoo Prairie, 274.
Kiruna, iron ores of, 294.
Kirghiz, 32f., 381ff.; animals of, 382; change in ways of life of, 385f.; clothing of, 385f.; diet of, 384f.; economic activities and migrations of, 382ff.; household possessions of, 384f.; life led by, 383f.; location of area occupied by, 382; physical characteristics of area occupied by, 382ff.; shelters of, 384f.
Klondike, 483.
Knobkerries, 373.
Kopjes, 369.
Köppen system of climatic classification, 637ff.
Kraal, 392.
Kraft paper, 472.
Krakatoa, eruption of, 69f.
Krivoi Rog district, 547.
Kuroshio, 137, 312.

Labor supply, industrial development as affected by, 545f.
Labrador, 37; iron ores of, 494.
Labrador current, 312.
Lacustrine deposits, origin and types of, 176f.
Lacustrine plains, agricultural use of, 265; city sites on, 265; drainage of, 265ff.; topography of, 263ff.
La Guardia Field, 535.
Lake Agassiz, 176; origin of, 262f.
Lake Eyre, 62.
Lake Louise, 286.
Lake of the Ozarks, 240.
Lake Superior, fogs of, 137.
Lake Tahoe, 241.
Lakes, areas of, 681; destruction of, 248ff.; fisheries of, 506f.; levels of, 246f.; levels of as affected by drainage, 88, 248ff.; obstacles to transportation, 191; preservation of levels of, 248f.; sources of water supply, 238f.; navigation of, 191ff.
Lakes to the Sea Waterway, 191, 194.
Lambert's equal-area azimuthal projection, 606f.
Land areas, United States, 683.
Landforms, subdivisions of, 251ff.
Land Hemisphere, 350.
Land survey, 624ff.; metes and bounds, 624ff.; United States, 625ff.; United States, history of, 625f.; township, range, and section, 625ff.
Land of the Midnight Sun, 628.
Land and sea breezes, 151f.
Landes, 514.
Landscape, features of, 52ff.
Lapps, 32, 56.
Laterites, 660ff.
Lateritic soils, 660f.
Latitude, measurement of, 631f.; value of degrees of, 613.
Lava flows, extent of, 68.
Lava plateaus, 69f.
Leaching, 96f.; effect of temperatures on, 118.
Leningrad, population of, 573.
Levees, artificial, 245; natural, 257.
Lexington, water supply of, 233f.
Lianas, 328.
Life, ocean, 313ff.
Limonite, 294.
Lisbon earthquake, 66.
Literature, effect of environment on, 57f.
Lithosphere, 160.
Llama, 517.
Llanos, 391, 641.
Location, factors producing change in value of, 354ff.; mathematical, 349f., 612ff.; relative, 349f.; strategic, 355ff.
Locational advantages, cities, 351ff., 353ff.; continents, 350f.; countries, 351f.; islands, 351ff.
Loess, 178f.
Long range weather prediction, 653f.
Longitude, measurement of, 614f.; time, 633ff.; value of degrees of, 613.
Longview, 472.
Los Angeles, growth of, 567; water supply of, 230f., 233f.
Lowlands, attraction of, 251f.; classes of, 251f.
Low plateaus, 272ff.
Lumbering, harvest of a crop, 466f.; importance of as an agency producing environmental change, 101f.; migratory, 466f.; use of caterpillar tractors in, 472; use of land after, 465f.
Lynch, a coal-mining community, 487ff.

Madera Canal, 224.
Magnetic declination, extremes of, 619; variation in, 619f.
Magnetic poles, 618.
Magnetite, 294.
Malthus, 16.
Man, areas of origin and earliest establishment of, 10ff.; areas of present establishment of, 10ff.; barriers to spread of, 10f.; beast of burden, 514ff.; civilized man and effects of environment on, 59f.; early man and environment, 58f.; evolution of his economic activities, 364ff.; modification of environmental opportunity by, 114f.; poleward march of civilized, 224ff.; primitive man and environment, 22f.; savage man and environment, 59f.
Manioc, 398.
Manoyuram, precipitation of, 146.
Maps, Aztec and Inca, 591; classes of, 600f.; compromises, 599f.; conformal, 599; earliest, 591f.; early Greek, 591f.; elements shown by, 599f.; errors in early, 591f.; Eskimo, 591; Marshall Islanders, 592; Medieval period, 594ff.; Mercator's, 596; modern, 597f.; topographic, 621ff.
Map projections, 599ff.
Map scales, 616ff.; change with reduction or enlargement, 616f.; common in use, 616f.; expressions of, 616f.
Mapping, development of, 591ff.; Far East and Moslem world, 594f.; modern, 597f.; progress in, 597.
Marco Polo, 5.

Mareepa, 406.
Market gardening, 442.
Marine west coast or "CFb" climate, 643ff.
Marsh grassland, 341f.
Martinique, effect of volcanic eruption on, 68.
Matterhorn, 285.
Mealies, 392.
Mechanization, of agriculture, 439f.
Medieval period, known world during, 4ff.
Mediterranean or "Cs" climate, 642ff.
Mediterranean, strategic problems of, 355.
Mercator's projection, 601ff.
Mercury, occurrences of, 302.
Mesa, 408.
Mesabi range, 489; origin of iron ores of, 489f.
Mesopotamia, soil erosion in, 111.
Mesothermal or "C" climates, 641ff.
Metallic minerals, commercial deposits of, 301f.; origin of deposits of, 301f.
Metes and bounds, survey by, 624ff.
Mexico, soil erosion in, 112.
Miami hurricane, 72.
Mica, 303.
Michigan, zoning of industry in, 555f.
Microthermal or "D" climates, 643ff.
Mile, nautical, 613.
Millibars, 162; conversion of to inches, 676.
Milo maize, 430.
Mineral resources, administration of, 95f.
Mineral wealth, effects of, 53f.; exhaustion of and effects of, 480f.; functions of, 304ff.
Mineralized regions, Americas, 302f.; Eastern Hemisphere, 302f.
Minerals, 291ff.; conservation of, 494ff.; exploitable occurrences of, 479ff.; fertilizers, 303ff.; importance of to man, 481f.; origin of commercial deposits of, 479ff.; sea water content of, 310; use of by early man, 291ff.; volume of deposit as it affects value of, 479f.
Minneapolis, suburban development of, 583f.
Mining, environmental change by, 94ff.; environmental opportunity as affected by, 95ff.; exploitive in type, 480f.; human culture and its effect on, 481f.; location as it affects, 483f.; occupancy of regions as affected by, 481f.; physical conditions of strata affecting, 482f.; relative importance of as an economic activity, 481f.
Mining cities, 565f.
Minnesota, development of iron mining in, 489ff.; future of iron mining in, 494; iron ores of, 489f.
Miquelon, 503.
Mississippi River, improvement of for navigation, 191.
Missouri Valley, projected improvement of, 207ff.
Mistral, 151.
Mollweide projection, 602f.
Monaco, size of, 52, 361.
Monsoon winds, 151f.
Mont Pelé, eruption of, 68.
Moors, 178.
Moroccan Tell, deforestation of, 474.
Moscow, population of, 573.
Mountains, 285ff.; barrier function of, 289f.; climates of, 285ff.; distribution of population in, 287f.; origin of, 285f.; passes of, 285f.; roads of, 287f.
Mountain sickness, 122f.
Mountain and valley breezes, 151f.
Muck, origin and characteristics of, 178.
Mule, use of as beast of burden, 516.
Muscle Shoals, 204.
Muskeg, 178.

Natural drainage, effects of, 53f.
Natural environment, factors of, 52ff.
Natural gas, 301f.
Natural levee, 69.
Natural vegetation, accommodation to temperature and precipitation of, 325ff.; climatic effects on, 325ff.; man's modification of, 345ff.; response to soil types by, 326f.; structure as affected by water supply, 326f.
Nature, interdependence of elements of, 585ff.
Nautical mile, 613.
Navajos, 385ff.; area occupied by, 385f.; economic activities and incomes of, 389f.; migrations of, 386f.; physical characteristics of area occupied by, 386ff.; population density in areas occupied by, 389f.; settlements of, 387f.
Naval stores, 472.
Navigation, development of, 321ff.; hazards of, 322f.; canal, 194ff.; lake, 191ff.; river, 184ff.
Negrillos, 375.
Nentsi, 255.
Neolithic period, 291.
Netherlands, canals of, 199; drainage in, 83ff.
Nevada, mining in, 482f.; value of mineral production of, 482.
New England, agricultural villages of, 562f.; industrial development in, 551f.; zoning of industries in, 555f.
New England Hurricane, 72, 155.
Newfoundland, fisheries of, 510ff.
New Madrid earthquake, 67.
New Orleans, site of, 560.
New York City, 575ff.; location of, 560; water supply of, 233f.
New York State Barge Canal, 195ff.
New Zealand, relative location of, 52.
Niagara Falls, power development at, 203ff.
Nitrates, 304f.
Nomadic hunting populations, 363ff.; dry areas, 369f.; polar areas, 369f.; rainy tropical areas, 375ff.
Nomads, pastoral, 380ff.
Nome, gold mining, 483.
Nonmetallic minerals, 303ff.
Novosibirsk, population of, 573.

Oceans, 308ff.; basins of, 309f.; climatic effects of, 320ff.; currents of, 312f.; depth and extent of, 308f.; importance of access to, 323ff.; importance of to man, 319ff.; life of, 313ff.; light in waters of, 310; mineral resources of, 321f.; movements of waters of, 310f.; nature of coasts of, 315ff.; recreational values of, 320f.; removal of dissolved minerals from, 310; salinity of waters of, 309f.; source

of food supply, 321f.; temperature of waters of, 310f.; use of as highways, 321ff.
Ocean basins, physical conditions of, 310f.
Ocean transport, 53, 532ff.; advantages of, 532.
Oceanic islands, life forms of, 351f.
Occidental agriculture, classification of types of, 433; commercial grain farming, 436ff.; dairying, 440ff.; evolution of present-day, 430ff.; general farming, 434ff.; interdependence associated with, 461f.; origin of, 429ff.; origin of animals of, 430f.; origin of crops of, 430ff.; specialized intensive types of, 442ff.; spread of, 429f.; tropical types of, 447ff.; types of, 432ff.
Odoric, 5.
Ohio River, use of for navigation, 189.
Oil pools, distribution of, 299f.
Oil sands, 298f.
Oil shales, 299.
Okefenokee Swamp, 253.
Okhotsk current, fogs of, 137.
Oklahoma City, oil wells of, 483.
Onas, 31, 369.
Orchards, location of, 118f.
Orient, industrial regions of, 549ff.
Oriental agriculture, 413ff.; advantage of rice as a crop of, 415f.; animal industries of, 424ff.; characteristics of, 414f.; farm size and pattern of, 420ff.; fertilizer use in, 423f.; Japanese, 419ff.; problems of Japanese, 425ff.; problems of regions of, 427f.; types of, 415.
Oriental populations, future, 45ff.
Orthographic projection, 606f.
Osaka, site of, 560.
Ostiaks, 369.
Outer Bluegrass, 269f.
Outwash plains, 260f.
Overgrazing, effects of, 92ff.
Owashio, fogs of, 137.
Ox, use of as beast of burden, 517f.
Ozark region, 272.

Paleolithic period, 291.
Palestine, soil erosion in, 111.
Pampa, modification of grassland by man, 93f.
Panama Canal, protection of by bases, 355f.
Paraná pine, 473.
Parker Dam, 233.
Pastoral nomadism, United States, 385f.
Pastoral nomads, 380ff.; latitudes occupied by, 380; life of, 380f.; migrations of, 380f.; material possessions of, 380f.; raids by, 381f.
Pearl fisheries, 499f.
Peat, 178ff.; agricultural use of, 179f.; conditions for formation of, 178f.; uses of, 179ff.; use of for fuel, 179f.
Pedalfers, 657ff.; classes and characteristics of, 659f.
Pedocals, 661ff.; classes and characteristics of, 662ff.
Pelagic fisheries, 499; catch of, 501.
Pennsylvania Turnpike, 522f.
Periodic winds, 151ff.
Perspective projections, 600.
Peru, fogs of, 137.
Peshtigo fire, 83.
Petroleum, 298ff.; Cumberland Plateau, 485f.; exhaustion of supply of, 301f.; origin of, 298f.; production in the Americas, 299 ff.; production in the Eastern Hemisphere, 300ff.; settlement as affected by, 483ff.
Phosphates, occurrences of, 304f.
Photosynthesis, 114.
Pioneers, effects of environment on, 59f.
Piranha, 402.
Pitcairn Island, 351.
Pitchblende, 302.
Pittsburgh, dust in air of, 133.
Pizarro, 22.
Plains, 251ff.
Planning, regional, 27ff., 63f.; environmental change as affecting, 76f.
Planets, 627.
Plans, city, 568ff.
Plantations, banana, 450ff.; crops of, 449ff.; future of rubber, 460f.; location of, 447ff.; native production as affected by, 449f.; Oriental rubber, 454ff.; ownership and operation of, 449f.; rubber, 454f.; rubber in Americas, 458ff.; value of as source of food supply, 449; value of as source of industrial raw materials, 449.
Plantation agriculture, 447ff.; economic and social conditions associated with, 449f.; initiation of, 447f.; types of, 450f.
Plantation areas, populations of, 460ff.
Plants, man's use of, 346ff.; temperatures as they affect, 116f.
Plant communities, character of desert, 328f.; character of forest, 327f.; character of grassland, 328f.; character of polar, 328f.; types of, 327f.
Plateaus, dissected, 276ff.; high, 274ff.; low, 272ff.; undissected, 272ff.
Platinum, occurrences of, 302.
Playas, 371.
Pliny, an advocate of erosion control, 111.
Podzols, 659ff.
Polar or "E" climates, 646ff.
Polar Easterlies, 149f.
Polar Eskimo, character of area occupied by, 365f.; clothing and utensils of, 367ff.; food preparation by, 367; food supply of, 367ff.; heating of shelters of, 366; hunting season of, 366; shelters of, 366ff.; sites occupied by, 366f.
Polar front, 150.
Polar highs, 149f.
Polar plant communities, 328f.
Poles, geographical, 618.
Poles, magnetic, 618.
Polyconic projection, 608ff.
Ponce de Leon, 22.
Population, anomalies of distribution of, 14, 15; areas of origin and establishment of, 10ff.; areas of present establishment of, 10ff.; barriers to spread of, 10f.; center of in the United States, 16; changes of in Asiatic areas, 44ff.; changes of in Europe, 42ff.; changes of in the United States, 46ff.; commercial, 40f.; commercial grazing, 32ff.; densities of as affected by environment, 18ff.; diffusion of, 11f.; distribution of civilized, 29ff.; distribution of by

continents, graph, 10; distribution of as affected by government, 19ff.; distribution of primitive, 29ff.; distribution of world population, 9ff.; effects of distribution of, 49ff.; farm (population) of the United States, map, 15; fishing as support of, 37ff.; growth of in the United States, 16f.; importance of distribution of, 16; increase of, 42f.; industry as support of, 40f.; interdependence of, 25ff.; Java, 9f.; location of areas of dense, 13f.; location of areas of sparse, 13f.; migratory hunting, 31ff.; migratory pastoral, 32ff.; mining, 39ff.; national security as affected by, 49ff.; Northern and Southern hemispheres, 9; Occidental agricultural, 36ff.; Oriental agricultural, 34ff.; plantation, 36f.; primitive agricultural, 33ff.; origin of present distribution of, 11ff.; prediction of future, 16ff.; present distribution of, 16f.; probable future of Europe, 43ff.; problems of China, 45f.; problems of areas with garden types of agriculture, 445ff.; problems of India, 45ff.; problems of Japan, 45f., 427ff.; progress as it affects distribution of, 29f.; resettlement of, 47ff.; rural and farm in the United States, 47ff.; rural in the United States, map, 14; spread of European, 44ff.; stage of development and change of, 42ff.; stage of development and distribution of, 29ff.; southeastern Asia, 9f.; supported by forest industries, 38ff.; surpluses, 48ff.; total for United States, map, 13; total for world, 9; map, 12; world total, past and present, 11ff.

Portland, Oregon, location of, 559.

Portolano charts, 594.

Ports, conditions necessary for development of, 319f.

Potash, occurrences of, 304f.

Portugal, cork production of, 475.

Portuguese exploration, 5, 6f.

Power projects, objectives of Federal, 204f.

Prairie, 328; cause of, 90; developed on outwash plains, 260; soils of, 660ff.; vegetation of, 339ff.

Precipitation, amount of, 145ff.; cause of, 139f.; desert, 146f.; distribution of, 144ff.; effect of on population distribution, 146; excessive, 146f.; factors affecting amount of, 145f.; forms of, 139ff.; important aspects of, 139f.; intensity of, 143f.; per cent of during April to September for the United States, 672; per cent of during June, July, and August for the United States, 672; summer for the United States, 670; variable value of, 146f.; winter for the United States, 671.

Predicting the weather, 653ff.

Pressure belts, 148ff.

Prester John, legend of, 5f.

Pribilof Islands, sealing of, 500f.

Prime meridians, in use, 614.

Primitive agriculture, 397ff.; Nigeria, 401f.

Prince Henry the Navigator, 6.

Projections, map, 599f.

Psychrometer, 130f.

Ptolemies, 591.

Ptolemy, Claudius, 6; map by, 591f.

Public water supply, 230ff.

Pueblos, 408.

Pygmies, 31; clothing and equipment of, 377f.; food supply of, 378f.; home of African, 375f.; Ituri, 375ff.; personal characteristics of, 378ff.; physical characteristics of home area of, 376f.; shelters of, 377f.; villages of, 377.

Pyramids, 517; construction of, 514.

Pytheas, contributions to geographic knowledge by, 4.

Quartz crystal, occurrences of, 303, 304.

Queensland, settlement of, 44.

Quito, temperatures of, 122.

Railroads, American, 527ff.; development of, 526ff.

Rain, artificial, 141; causes of, 140f.

Rain shadow, 145.

Range line, 626.

Ratoon crops, sugar cane, 453.

Raw materials, industrial development as affected by, 544ff.

Recreation, use of inland waters for, 238ff.

Rectangular projection, 610.

Red River Valley, water supply of, 227.

Red Sea, salinity of, 310.

Red and yellow soils, 659ff.

Reelfoot Lake, origin of, 67.

Reforestation, desirability of, 477f.

Reindeer, use of as beast of burden, 517f.

Relative humidity, indoor, 131ff.; sensible temperature as affected by, 128f.; statement of, 128f.; tables, 675; water requirements of crops as affected by, 131f.

Relative location, 349ff.

Relief, representation of on a map, 621f.

Religion, environmental effects on primitive, 57f.

Residential cities, 565f.

Residual material, soils derived from, 174f.

Resort business, California, 240; Michigan, 240ff.; Minnesota, 240f.

Resort cities, 564f.

Retardation, 60ff.

Retrogression, 62ff.

Rhine River, use of for navigation, 184.

Rice, advantages of as a crop in Oriental agriculture, 415f.; habitat of, 416ff.; importance of as a crop in Japan, 421ff.; planting and harvest of, 423f.; progress as affected by, 418ff.; reasons for importance of as a crop in Japan, 421ff.; spread of crop, 417f.; yields in Japan, 422f.

Rice lands, extent and population of, 415f.; Java an example of, 418ff.

Rivers, conditions under which improvement of for navigation is desirable, 184ff.; extent of use of for navigation, 184ff.; factors affecting value for use of in development of power, 202f.; homes for "floating populations," 238f.; important river highways of the United States, 189f.; integration of improvement of, 242ff.; lengths of, 682; miscellaneous uses of, 238ff.; physical conditions of as they affect use of for navigation, 185ff.; physical conditions of as they affect use of for power, 202ff.; unwise improvement of for navigation in the United States, 189ff.; use of during the Colonial period and later settlement of the interior of North America, 184.

Roads, Chinese, 524f.; early American, 521f.; Medieval period, 521f.; planned for the United States, 524f.; recent in the United States, 522ff.; Roman, 520f.
Rubber, history of use of, 454ff.
Rubber plantations, Americas, 458ff.; "Ford," 458ff.; future of, 460f.; labor supply of Oriental, 456; location of, 454f.; Oriental, 454ff.; returns from, 458f.
Rural land use, United States, 664.

Sacramento River, 224.
St. Helena, 351.
St. Louis, dust in air of, 133f.; location of, 559.
St. Paul, advantages of location of, 560.
St. Pierre, 503; destruction of, 68.
Saline minerals, 303f.
Salmon, varieties and habits of, 504ff.
Salmon fisheries, 504ff.
Salt Lake Oasis, 217.
Salt River Irrigation Project, change of soils in, 99.
Samelats, 32.
Samoyedes, 369.
San Joaquin River, 224.
Sand dunes, values of, 176f.
Sandalwood, 467.
San Francisco, expansion of, 583f.; water supply of, 230.
San Francisco earthquake, 67.
San Marino, 361.
Sanson-Flamsteed projection, 607f.
Savanna or "Aw" climate, 640ff.
Savannas, 328; vegetation of, 339.
Scrub and thorn forest, 331f.
Seas, areas of, 681; effects of contact with, 53f.
Sea hunting, 500ff.
Sealing, 500ff.
Seaports, great cities, 560.
Seasons, cause of, 629ff.
Seattle, city site and plan, 571f.; precipitation of, 143; site of, 560; water supply of, 233f.
Secondary wind circulation, 153ff.
Seeds, function of, 114f.
Seines, 501.
Selkirks, Canadian, recreational assets of, 286, 289f.
Semiplantation agriculture, 461f.
Sensible temperature, 130.
Shanghai, growth of, 567; locational advantages of, 559; site of, 560.
Shasta Dam, power development at, 224.
Sheep, grazing of, 394ff.
Sheet erosion, areas of occurrence of, 102.
Ship canals, 198f.
Siberia, forest resources of, 474.
Siderite, 294.
Sierozems, 665f.
Silting, of irrigation reservoirs, 218.
Silver, occurrences of, 302.
Simla, 289.
Sink holes, 230f.
Sinusoidal projection, 607f.
Sirocco, 158.
Sitka spruce, 473.
Size, contrasts of in areas, 359f.; expressions of for areas, 360f.
Skagway, 483.
Sledges, use of, 517f.
Sleet, cause and effects of, 141f.
Sling psychrometer, 129.
Small areas, characteristics of, 360f.
Smog, 135.
Smoke, damage by, 133f.
Snow, beneficial effects of, 143f.; detrimental effects of, 143.
Snowfall, for United States, 673.
Social organization, environmental effects on, 57ff.
Soddies, 55.
Soil classification, American, 657ff.; basis for, 657ff.
Soil erosion, areas of other than the United States, 111ff.; causes of, 102f.; effects of on streams, 109f.; extent of in the United States, 103; losses from, 107ff.; mineral plant nutrients lost in association with, 109f.; percentage of the United States affected by, 107f.; prevention of, 109ff.; seriousness of in southeastern United States, 103ff.; types of, 102ff.; where most prevalent in the United States, 103f.
Soil mining, 111, 174ff.
Soils, change in, 170f.; classification of, 179ff.; cold and warm, 173; components of, 170ff.; composition of, 174ff.; derived from eolian material, 176f.; derived from transported material, 175f.; desirability of as affected by texture, 173f.; desirability of if derived from lacustrine deposits, 170f.; diet as affected by, 170; effects of, 53f.; factors affecting agricultural desirability of, 170f.; factors affecting depth of, 170ff.; forest, 180; formation of in dry areas, 99f.; grassland, 180; high temperatures as they affect, 118f.; light and heavy, 173; limitation of if derived from residual material, 175f.; low temperatures as they affect, 118f.; mineral deficiencies in, 174f.; misuse of, 180ff.; organic, 178ff.; structure of, 173ff.; texture of, 173ff.; irrigation water as it affects, 99f.; without profiles, 665f.
Solar relations, 627ff.
Solstices, 628.
Soot, amount of in the air, 133.
Soviet Union, size of, 52; urban development in, 573f.
Space relations, 52ff., 349ff.
Sphagnum moss, 179, 343.
Sponge fisheries, 499f.
Springs, 229f.
Springfield, 274.
Springfield Plain, 274ff.; elevation and topography of, 274f.; land use of, 274f.; mineral wealth of, 274f.; natural drainage of, 274f.; settlement of, 274f.; soils of, 274f.
Stalinsk, 550.
Standard Time, 635ff.
States, compact and attenuated, 356ff.; small, 361f.
Steppe or "BS" climate, 647ff.
Steppe, 328; definition of, 392.
Stereographic projection, 606.
Stockton, a port, 189.

Strabo, 6.
Strategic locations, 355ff.; classes of, 355; examples of, 355ff.
Strategic minerals, metallic, 303; nonmetallic, 304f.
Stratosphere, 160f.
Stratus clouds, 137.
Strip cropping, 110.
Subpolar or "Dfc" and "Dwc" climates, 645ff.
Subpolar lows, 149f.
Subsistence agriculture, 433ff.
Subtropical highs, 149.
Suburban development, basis for, 582ff.; extent of, 583ff.
Sudan, 391.
Suf, dunes of, 56.
Sugar, cane, 451ff.; "centrals," 453; production of, 451ff.; production of in Cuba, 453ff.; use of by plants, 114f.
Sulphur, 303f.
Sun, size of, 627.
Sun or local time, 635.
Sunlight, its function, 114ff.
Sunshine, average winter for the United States, 668; effects of on agriculture, 115f.; effects of on crop systems, 115; effects of on crop yields, 115.
Sunshine Country, the, 276.
Surface waters, effects of drought on, 227f.; mineralization of, 227.
Survey, land, 624ff.
Swamps, forests of, 336f.; soils of, 651.
Sweden, forest industries of, 475.
Sydney, 560.
Synoptic charts, 651.

Tables, 674.
Taconite, 494.
Tahoe, Lake, recreational use of, 241.
Taiga, characteristics of, 332, 474.
Tata Iron and Steel Works, 550.
Teak, production of, 467f.
Tehuelchians, 375.
Temperate zone, 162.
Temperatures, 114ff.; animals as affected by low, 117f.; average summer for the United States, 667; average winter for the United States, 668; factors affecting distribution of, 115f.; Fahrenheit and Centigrade, 674; ocean water, 310f.; plants, animals and man as affected by high, 118ff.; plants, animals and man as affected by low, 118f.
Temperature efficiency, 117f.
Temperature range, annual as it affects animals, agriculture and man, 122ff.; daily as it affects crops and man, 121ff.; hottest and coldest times of day, 121f.; variation in annual, 121f.; types of, 121f.
Tennessee, attenuation of, 357f.
Tennessee River, improvement of for navigation, 191f.; navigability of, 207f.; physical conditions of, 207ff.; variability of flow of, 207f.
Tennessee Valley Authority, 204ff.; allocation of costs by, 205f.; power development by, 205ff.
Terminal moraine, 260f.
Terraces, river, 257.
Thar, precipitation of, 146.
Thermometer scales, 674.
Thunder storms, 165f.
Tides, advantages of, 311f.; cause of, 311f.; height of, 311f.
Tien Shan, 382.
Tierra del Fuego, 31, 369.
Till, deposition of, 176f.; productivity of, 176f.
Till plain, 260f.
Tilth, 173.
Time, measurement of, 632ff.; standard, 635ff.
Time capsule, 614f.
Tin, occurrences of, 302.
Tokyo, growth of, 561, 567.
Tokyo earthquake, 67.
Topographic maps, 621ff.; colors used on, 622f.
Topography, conditions of favoring irrigation, 215; effects of, 53f.
Tornadoes, 156ff.; areas of greatest frequency, 165; paths of and destruction produced by, 71ff.; seasons of occurrence of, 71.
Township, range and section land survey, 625ff.
Trade, interdependence and, 25ff.
Trade routes, change in, 541ff.; location of, 541ff.
Trade winds, 149f.
Transhumance, 383.
Transportation, 514ff.; air, 532ff.; evolution of, 514ff.; ocean, 531ff.; river and canal, 525ff.; trade as affected by, 25ff.; without wheels, 517f.
Trawls, 501.
Tropical or "A" climates, 637ff.
Tropical cyclones, 154ff.
Tropical forests, exploitation of, 467f.; industries of, 466ff.
Tropical grasslands, 339f.
Tropical hardwoods, lumbering of, 466ff.
Tropical rain forest or "Af" climate, 637ff.
Tropical plantations, crops of, 449f.; future of in Middle America, 461f.; location of, 447ff.; native production as affected by, 449f.; ownership and operation of, 449f.
Tropical year, 632.
Tropopause, 160.
Troposphere, 160f.
Truck gardening, 442.
Tundra or "ET" climate, 646ff.
Tundra, fauna of, 346f.; vegetation of, 343ff.
Tungsten, occurrences of, 302.
Tupic, 366.
Turpentine, production of, 472.
Tuscarora deep, 285.
Tusayan, extent of, 407f.
Twin Cities, suburban development of, 583f.
Typhoons, 154; damage by, 73ff.

United States, agricultural regions of, 664; beginnings of forest industries in, 467f.; center of population of, 16; distribution of farm population of, 15; distribution of rural population of, 14; distribution of total population of, 13; growth of population of, 16f.; land survey of, 625ff.; population change in, 46ff.; rural and farm population of, 47ff.; total areas of, 683.

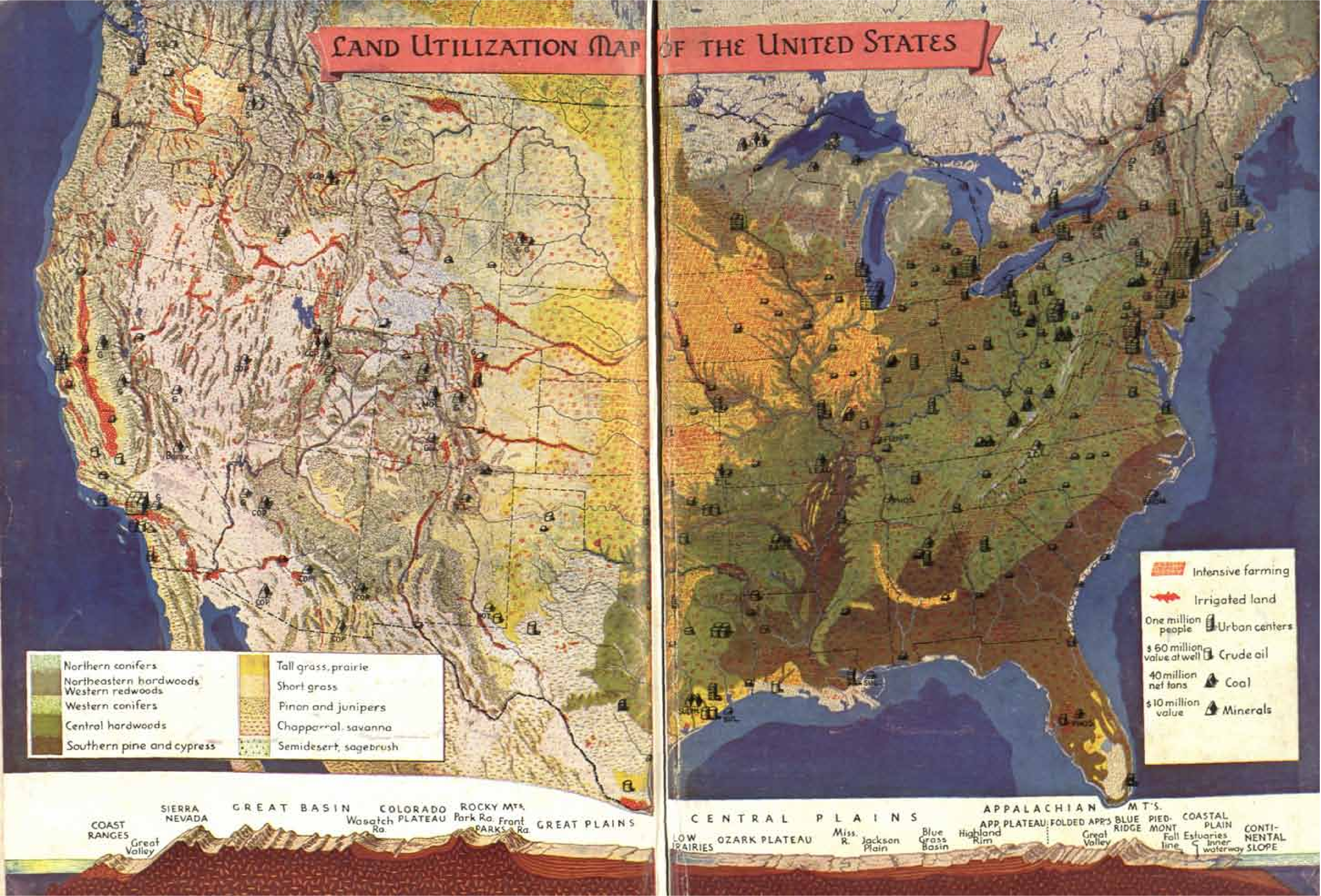
United States Geological Survey, topographic maps of, 621ff.
Union of South Africa, grazing industry of, 392ff.
Uranium, occurrences of, 302.
Urban development, United States, 573ff.; areas of extensive, 573f.
U.S.S.R., access to sea of, 323f.; industrial development of, 550f.

Vasco da Gama, explorations of, 6.
Valley authorities, 204ff.
Valley of California, origin of, 257.
Vegetation, desert, 341ff.; man's modification of natural, 345ff.; tundra, 343ff.
Vehicles, evolution of wheeled, 518ff.
Veldt, 392.
Verkhoyansk, amount and distribution of precipitation of, 126; temperatures of, 118.
Vermilion range, 489.
Vesuvius, 68.
Villages, agricultural in the United States, 562ff.; functions of, 562; serving needs of primitive populations, 558f.
Volcanic ash, 68.
Volcanic cones, shapes of, 67.
Volcanic eruptions, cause of, 67; types of, 67.

Washington, D. C., city plan of, 571.
Water, areas of United States, 683; forms of, 126f.; variability in salinity of ocean, 310.
Water Hemisphere, 350.
Waterlogging, 99f.
Waterspouts, cause of, 156.
Water supply, a critical environmental factor, 226f.; contamination of, 227ff.; objectionable impurities in industrial, 234ff.; organic pollution of, 228ff.; ownership of public, 231f.; rural United States, 229ff.; sources of, 226f.; sources of contamination of, 227f.; sources of public, 230ff.; underdeveloped areas, 228f.
Watwa, 376.
Waves, caused by earthquakes, 311; wind driven, 310f.
Weather, change of, 167f.; doldrum belt, 161f.; intermediate latitudes, 161f.; subtropics, 161f.; trade wind areas, 161f.; tropical, 161f.
Weather charts, 651f.
Weather elements, 167f.
Weather forecasts, value of, 653f.
Weather forecasting, 651ff.
Weather maps, typical, 654.
Weather prediction, 651ff.; basis for, 166ff.; long range, 167f., 653f.; value of, 653f.
Weather proverbs, 126, 167f.
Weathering, an agency producing environmental change, 76.
Westerlies, 149f.
Whaling, 500ff.
Wild life, drainage as it affects, 88f.
Winds, definition of, 148; man as affected by, 148f.; strength of, 148; weather as affected by, 160f.
Wilson River fire, 83.
Wind erosion, areas where prevalent, 105.
Wind storms, types of, 71.
Winnipeg, Lake, relation to Lake Agassiz, 263.
Winnipegosis, Lake, relation to Lake Agassiz, 263.
Works of man, effects of environment on, 54ff.
World, growth of knowledge of, 4ff.

Yahgans, 369.
Yak, 380, 382, 517.
Yangtze River, use of for navigation, 184.
Yap, stone money of, 56.
Year, length of, 632; tropical, 632.
Yerba matè, 473.
Yosemite, recreational assets of, 288.
Yuma, temperatures of, 118.
Yuraks, 31.
Yurt, 384.

Zebu, 391.
Zinc, occurrences of, 302.
Zoning of industry, 555f.
Zuider Zee, drainage of, 83f.
Zulus, 392.


LAND UTILIZATION MAP OF THE UNITED STATES
Northern conifers
Northeastern hardwoods
Western redwoods
Western conifers
Central hardwoods
Southern pine and cypress
Tall grass, prairie
Short grass
Pinon and junipers
Chapparral, savanna
Semidesert, sagebrush
Intensive farming
Irrigated land
One million people
Urban centers
$60 million value at well
Crude oil
40 million net tons
Coal
$10 million value
Minerals
COAST RANGES
Great Valley
SIERRA NEVADA
GREAT BASIN
Wasatch Ra.
COLORADO PLATEAU
ROCKY MTS.
Park Ra.
PARKS
Front Ra.
GREAT PLAINS
CENTRAL PLAINS
LOW PRAIRIES
OZARK PLATEAU
Miss. R.
Jackson Plain
Blue Grass Basin
Highland Rim
APPALACHIAN MT'S.
APP. PLATEAU
FOLDED APP'S
Great Valley
BLUE RIDGE
PIED-MONT
Fall line
COASTAL PLAIN
Estuaries
Inner waterway
CONTI-NENTAL SLOPE